An *in vitro* comparison of four photoactivated disinfection systems in the lethal photosensitisation of *E. faecalis* in root canals.

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Declaration

I, Michael Tongbang Lee of 8/31 High Street, Lutwyche solemnly declare that the work presented in this report is, to the best of my knowledge and belief, original, except as acknowledged in the text. Although the articles contained are multi-authored and contribution of the co-authors is greatly appreciated, their input was mainly advisory and the bulk of the laboratory work and writing was carried out by myself. The material presented has not been submitted, either in part or in whole for another degree at this or any other university.

Declared by: Witnessed by:

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Date: __________ Date: __________

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Paper 1

Literature Review

Photoactivated disinfection of the root canal:

a role for lasers in endodontics

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Paper 1: Literature review

Abstract

Micro-organisms play a crucial role in the development of pulpal and periapical disease. The prognosis of endodontic therapy is therefore intimately related to the presence of bacteria within the root canal system. In recent years, the number of people seeking endodontic treatment has dramatically increased as patients choose root canal treatment over tooth extraction. However, epidemiological population studies of endodontic treatment performed by general practitioners reveals a high rate of apical periodontitis associated with endodontically treated teeth. In most cases, failure of endodontic treatment is a result of micro-organisms persisting in the apical region of the root canal system. The apical region of the root canal space often remains untouched during chemomechanical preparation, regardless of the techniques and instruments employed.

Lasers that are commercially available for dental use are usually classified as either ’soft’ or ‘hard’ lasers, depending on the power output of the device. Although several studies have demonstrated the efficacy of ‘hard lasers’ such as the CO_2, Nd:YAG and Er:YAG lasers for disinfection of the root canal, undesirable effects such as carbonisation, cratering, crack propagation and heat induced injury to the adjacent periodontal tissues remain a concern and limit the usefulness of these lasers. An alternative approach to microbial killing by laser light involves the use of low power lasers, such as the HeNe or the semi-conductor diode lasers, to drive photochemical effects. The use of low-level laser light has advantages in that the antimicrobial effect can be achieved without damaging host tissues, and with little optical danger to the operator and patient.

Several studies have shown that virtually all species of bacteria can be killed by visible light after they have been treated with an appropriate photosensitiser. Laser radiation emitted from a low power laser device activates a dye (photosensitiser) to produce singlet oxygen and free radicals, which in turn exerts a lethal effect on bacteria. This has led to the concept termed Photo Activated Disinfection (PAD), in which lethal photosensitisation occurs. This article reviews the potential of PAD in endodontics. A range of photosensitisers have been investigated, and their mode of action is now well understood. Although *in vitro* studies of the use of low-level laser light to kill photosensitised oral bacteria have been encouraging, there have been only limited studies of its ability to kill micro-organisms *in vivo* in the root canal system. While PAD can be undertaken as part of the routine disinfection of the root canal system, it has potential to be particularly useful for eradicating persistent endodontic infection, for which conventional methods have been unsuccessful.

Introduction

The development of the ruby laser in 1960 (Maiman 1960) was greeted by the dental profession with great interest because it had the potential to redefine established treatment techniques.

Lasers that are commercially available for dental use are usually classified as either ’soft’ or ‘hard’ lasers, depending on the power output of the device. Alternatively, laser devices can also be classified according to the effects produced by laser light on living cells, tissues or organisms (Wilson 1994). These laser effects may be (1) photochemical, due to the production of free radicals and other reactive species; (2) photothermal; (3) photoablative, due to the breaking of chemical bonds; or (4) photomechanical, due to shock waves produced by the dissipation of plasma. In general, soft lasers induce only photochemical changes while hard lasers may produce any, or all of the above four effects depending on the type of laser and the conditions under which it is operating.

	Low power lasers	High power lasers
Power output	Usually several mW	Usually greater than 500 mW
Wavelength of the light emitted	Visible (usually red) or near infrared-red	May be ultra-violet, visible or infrared-red
Effect on cells	Photochemical only	Predominantly photothermal, photoablative, or photomechanical
Examples	Helium-Neon Gallium Aluminium arsenide	Carbon dioxide Argon ion Nd:YAG, Er:YAG

Modified from Wilson (1994)

High power, heat-generating lasers, such as carbon dioxide and Nd:YAG surgical lasers, have a well recognized destructive effect on bacteria, and this has led to the development of techniques for sterilising wounds, carious lesions and root canals (Adrian et al. 1979; Mehl et al. 1999; Moshonov et al. 1995; Powell et al. 1991). These lasers typically require an energy output of approximately 100J for most ‘sterilizing’ applications, which has been found to be associated with an increased risk of thermal injury (Walsh 1993; Walsh 1997).

In terms of safety, the extent of thermal change which can be tolerated by vital tissue has been defined by both animal and human *in vivo* studies. Zach and Cohen (1965) evaluated the thresholds for adverse pulpal response to intra-pulpal temperature rises. Temperature rises below 2.2 degrees Celsius did not produce any histological damage in the pulp. However, since temperature increases greater than 5.5 degrees Celsius consistently resulted in necrosis, this value is regarded as the threshold value for tolerating thermal insults when assessing the potential for heat-related pulpal injuries during the use of lasers and other energy sources in dentistry. The thermal changes that will occur on the tooth surface with laser treatment are dependent upon the density, energy and laser wavelength delivered. With no appropriate literature describing safe thermal limits with respect to periodontal ligament cells, it is necessary to extrapolate the thermal limits for pulpal cells to those for cells on the external root surface. In this context, it can be considered that if temperature increases are less than 2.2^oC, no adverse effects on the periodontal tissue are likely.

Micro-organisms play a crucial role in the development of pulpal and periapical disease (Kakehashi et al. 1965). The prognosis of endodontic therapy is therefore intimately related to the presence of bacteria within the root canal system (Sjogren et al. 1997). As

current concepts of orthograde endodontics are based on the removal of microbiological agents, much emphasis is placed on root canal disinfection by mechanical, chemical and anti-microbial methods. However, residual pulpal tissues, micro-organisms and dentine debris may persist in the root canal system, despite meticulous mechanical preparation (Abou-Rass et al. 1982). Direct killing of residual bacteria within the root canal system would be a valuable adjunct to existing strategies which rely on broad-spectrum anti-microbial agents as medicaments. To this end, various laser devices have been examined as adjuncts to chemical disinfection in endodontic therapy. Although several studies have demonstrated the efficacy of ‘hard lasers’ such as the CO_2, Nd:YAG and Er:YAG lasers for disinfection of the root canal (Klinke et al. 1997; Le Goff et al. 1999; Mehl et al. 1999), undesirable effects such as carbonisation, cratering, crack propagation and heat induced injury to the adjacent periodontal tissues remain a concern and limit the usefulness of these lasers (Turkmen et al. 2000).

An alternative approach to microbial killing by laser light involves the use of low power lasers to drive photochemical effects. Although the viability of many bacteria is largely unaffected by light in the visible region of the electromagnetic spectrum, several studies have shown that virtually all species of bacteria can be killed by visible light after they have been treated with an appropriate photosensitiser (Malik et al. 1990; Spikes et al. 1987). More recently, Wilson (1992) reported that a range of oral bacterial species can be killed by red light from a low power helium-neon (HeNe) laser following sensitisation with various dyes.

This has led to the concept termed Photo Activated Disinfection (PAD), in which lethal photosensitisation occurs. Laser radiation emitted from a low power laser device activates a dye to produce singlet oxygen and free radicals, which in turn exerts a lethal effect on bacteria. This PAD of micro-organisms is a specific interaction, in that treatment with the laser alone, or with dye alone, produces minimal effects. However, when exposure to the dye is followed by laser irradiation, changes within the dye produces reactive oxygen species that cause injury and death of the bacteria cells. In this regard, it is essential to match the laser wavelength used with the dye, as well as ensuring that the dye itself does not bind to human cells or exert toxic or irritant effects on human tissues.

Endodontic microbiology

The causal relationship between bacterial infection and pulpal and periradicular diseases was elegantly demonstrated by the seminal work of Kakehashi and colleagues in the early 1960's (Kakehashi et al. 1965). When the healing response following pulp exposure in germ-free and conventional rats was compared, they were able to show that sites of mechanical pulp exposure in germ-free animals could heal by the formation of calcific bridges, whereas pulpal necrosis and apical periodontitis was consistently the outcome in conventional rats.

Since then, the area of endodontic microbiology has been studied in detail. Using strict anaerobic recovery procedures as described by Möller (1966), Sundqvist (1976) found a predominance of anaerobes in necrotic teeth with intact pulp chamber walls. Although 88 bacterial strains were isolated, the composition of the microflora varied and no more

than 12 strains could be isolated from any one tooth. The bacteria most frequently isolated were the *Fusobacterium, Bacteriodes, Eubacterium, Peptococcus, Peptostreptococcus* and *Campylobacter* species. This result was corroborated in a series of investigations by Möller et. al. (1966; 1981). In 52 teeth that were deliberately devitalised and infected by indigenous oral flora, 47 developed clinical and/or radiographic signs of apical periodontitis at the end of the experimental period (6 months). The number of bacterial strains that could be isolated in each canal averaged around 8-15, of which facultative anaerobes (such as α-haemolytic streptococci, enterococci, and coliform rods) and obligate anaerobes (such as *Bacteriodes, Eubacterium, Propionibacterium* and *Peptostreptococcus*) were the most commonly detected micro-organisms.

Although all oral commensal micro-organisms have the theoretical capability of entering the root canal space, the selective pressures within the infected root canals mean that only a limited group of the oral flora can persist and flourish in this site. The dynamics of root canal infections were examined in a series of experiments using monkeys (Fabricius 1982; Moller et al. 1981). Pulp chambers of monkey teeth were exposed to the oral environment for 7 days, and then sealed for the rest of the experimental period. Microbiologic samples taken from the root canals at 7 days, 90 days, 180 days and 1060 days were then analysed for quantitative changes in the bacterial species, and their effect on the development of apical periodontitis. At the end of the experimental period, all teeth showed radiographic signs of pathological changes. Where obligate anaerobes constituted 50-55% of the total number of bacteria at the initial sampling at 7 days, their numbers increased markedly to 85% after 90 days and to 98% after 1060 days. These results showed that mixed infections have the greatest

capacity of inducing apical periodontitis, and that the *Bacteroides* species predominated in most of the mixed infections in root canals (Fabricius et al. 1982). There is now a consensus of opinion that the root canal micro-flora of teeth with necrotic pulps and a diseased periapex is dominated by obligate anaerobes (Haapasalo 1989; Peters et al. 2002; Sundqvist 1976; Sundqvist et al. 1989; van Winkelhoff et al. 1985), belonging to the genera *Fusobacterium*, *Porphyromonas* (formerly *Bacteroides*), *Prevotella* (formerly *Bacteroides*) *Eubacterium*, and *Peptostreptococcus*.

Obligate anaerobes	Facultative anaerobes
Gram-positive cocci *Streptococcus* *Peptostreptococcus*	**Gram-positive cocci** *Streptococcus* *Enterococcus*
Gram-positive rods *Actinomyces* *Eubacterium* *Propionibacterium*	**Gram-positive rods** *Actinomyces* *Corynebacterium* *Lactobacillus*
Gram-negative cocci *Veilonella*	**Gram-negative cocci** *Neisseria*
Gram-negative rods *Porphyromonas* *Prevotella* *Fusobacterium* *Selenomonas* *Treponema* *Camplylobacter*	**Gram-negative rods** *Capnocytophagia* *Eikenella*

Table 1. Important microbial genera of endodontic infections. Reproduced from Nair (1997)

In recent years, the number of people seeking endodontic treatment has dramatically increased due to patients choosing root canal treatment over tooth extraction. Current information on the quality and prognosis of root canal treatment has mainly been based on clinical studies made in controlled environments at dental schools or in specialist

practices (Kerekes et al. 1979; Sjogren et al. 1990; Strindberg 1956). The results from such longitudinal studies show success rates of up to 96% for periapical health after endodontic treatment. Epidemiological population studies of endodontic treatment performed by general practitioners show a less positive picture. They reveal a high frequency of inadequate root fillings, and a high rate of apical periodontitis associated with endodontically treated teeth (De Cleen et al. 1993; Petersson et al. 1986; Saunders et al. 1997). In most cases, early failure of endodontic treatment is a result of micro-organisms persisting in the apical region of the root canal system, even when the root canal filling appears to be adequate radiographically (Nair et al. 1990). In contrast, late failure is typically due to coronal leakage (Diaz-Arnold et al. 1990; Metzger et al. 2000).

The apical region of root canal space often remains untouched during chemomechanical preparation, regardless of the techniques and instruments employed (Dalton et al. 1998; Lin et al. 1991; Siqueira et al. 1997). Furthermore, bacteria located in areas such as the isthmus, various ramifications, deltas, irregularities and dentinal tubules may be unaffected by endodontic disinfection procedures (Sen et al. 1995; Siqueira 2001). The microbiota associated with failed cases is markedly different from that found in untreated teeth (i.e. primary root canal infections). Whilst Gram-positive facultative bacteria, including *Enterococcus faecalis*, is restricted to only a few cases of primary root canal infections, it is frequently isolated from secondary and or persistent root canal infections, usually as the single species of micro-organism present. (Hancock et al. 2001; Sundqvist et al. 1998). Molander (1998) reported that *Enterococcus faecalis* could be isolated from 78% of previously root filled teeth with radiographic evidence of apical periodontitis. In a prospective study of the outcome of conservative retreatment,

Sundqvist et al. (1998) observed a mean of 1.3 bacterial species per canal of which only 42% of the recovered strains were anaerobic bacteria; *Enterococcus faecalis* was isolated in 38% of the teeth that had recoverable micro-organisms. The frequent recovery of *Enterococcus faecalis* from canals in cases of failed endodontic treatment suggests it is a major opportunistic pathogen which is difficult to eradicate. The failure rate of retreatment is also higher if *Enterococcus faecalis* can still be recovered from the root canal at the time of root filling. This impacts on the success rate of retreatment, which in this study was found to be 74%.

Once established in the root canal, *Enterococcus faecalis* is difficult to remove. *In vitro* studies have shown that *Enterococcus faecalis* can survive for up to 10 days after the withdrawal of nutrient support (Orstavik et al. 1990). In the cleaned and obturated canal, *Enterococcus faecalis* may remain viable by deriving nourishment from tissue fluid (Love 2001). Several studies have reported that *Enterococcus faecalis* appears to be highly resistant to conventional antimicrobial agents used during treatment, such as the alkaline pH of calcium hydroxide (Bystrom et al. 1985a; Haapasalo et al. 1987; Siqueira et al. 1998). Evans (2002) showed that the survivability of *Enterococcus faecalis* is dependent on the function of its proton membrane transport system. While *Enterococcus faecalis* could survive at a pH of 11.5 or less, the ability of the membrane proton pump to maintain cytoplasmic pH homeostasis could be rapidly overwhelmed in an even more alkaline environment. Due to the buffering effect of dentine (Nerwich et al. 1993; Wang et al. 1988), it is unlikely that the high pH of pure calcium hydroxide (>11.5) is attained within dentinal tubules where *Enterococcus faecalis* has the capacity to penetrate deeply (Haapasalo & Orstavik 1987; Peters et al. 2000). In radicular

dentine, the alkalinity may only reach pH 10.3 after dressing the canal with calcium hydroxide (Minana et al. 2001; Nerwich et al. 1993).

Furthermore, yeast-like micro-organisms have also been found in the obturated root canals of teeth in which treatment has failed (Nair et al. 1990). The clinically important *Candida* species has been documented to tolerate a wide range of different pH environments, and this characteristic is believed to be responsible for their resistance to calcium hydroxide medicaments (Bystrom et al. 1985a; Waltimo et al. 1999).

Current regimes used in the management of endodontic infection

The primary objective of root canal treatment is to eliminate micro-organisms from the infected root canal system, so that a favourable environment that is conducive to healing can be created. Several studies have shown that it is impossible to achieve a bacteria-free root canal space in all cases, even after thorough cleaning, shaping and irrigation. Bystrom and Sundqvist (1981) cultured 15 necrotic teeth after instrumentation with saline irrigation. Although they found a 100-1000 fold reduction in the bacterial counts, no teeth were bacterial free after the first appointment. The addition of irrigating solutions was found to further improve bacterial elimination (Bystrom et al. 1983), however effective antibacterial activity of sodium hypochlorite could only achieved when the apical enlargement was in excess of #30-35 (Shuping et al. 2000). Whilst the use of files specifically for greater apical enlargement may be beneficial in terms of debridement of apical root canals, Tan (2002) and Card (2002) cautioned against this because of iatrogenic errors such as canal transportation, root perforation and

instrument failure. More recently, chlorhexidine and MTAD (containing a mixture of tetracycline isomer, citric acid and a surfactant) were also investigated as potential root canal irrigating solutions (Podbielski et al. 2003; Torabinejad et al. 2003; Yamashita et al. 2003)

In persistent endodontic infections, it has been observed that the penetration of the bacteria into the dentinal tubules can range from 10 to 150µm (Sen et al. 1995). Bystrom et al (1985b) have shown that chemomechanical preparation alone is not enough to predictably eliminate all the bacteria from the root canal. Consequently, a well-sealed inter-appointment antimicrobial dressing is generally advocated to prevent recovery of the residual bacteria population (Bystrom et al. 1985a).

Ledermix paste is a glucocorticosteroid-antibiotic compound that contains as its active components, triamcinolone (a glucocorticosteroid) and demethylchlortetracycline (demeclocycline, a tetracycline antibiotic) at concentrations of 1 percent and 3.21 percent respectively (Abbott 1990). Demeclocycline is generally thought to be effective against most of the common endodontic bacteria at a concentration ranging from 0.05 to 128 mg/L (Abbott et al. 1990). Since demeclocycline is present within Ledermix paste at a concentration of 50,000 mg/L (3.21%), it is expected that this material should be very effective as an antimicrobial agent within the root canal. The use of Ledermix as a root canal inter-visit dressing has been advocated for all cases involving inflammation and/or infection associated with the root canal system and the periapical tissues. Ledermix has been reported to reduce the incidence of pain following initial endodontic debridement (Ehrmann 1965; Schroder 1962) and reduces the severity of inflammatory root resorption (Bryson et al. 2002; Pierce et al. 1987).

Calcium hydroxide is a strong alkaline substance with a pH of 12.5. In aqueous

solution, calcium hydroxide dissociates into calcium and hydroxyl ions. Various biological properties have been attributed to this substance. Sjogren et al. (1991) found that the use of calcium hydroxide as a dressing for one week effectively eliminates bacteria. Calcium hydroxide has also been shown to promote the formation of calcified tissues (Cvek et al. 1976; Foreman et al. 1990). Its ability to denature protein aids in the dissolution of remnants of pulpal tissue within the root canal space (Andersen et al. 1992; Hasselgren et al. 1988).

The antibacterial effect of calcium hydroxide is related to the release of highly reactive hydroxyl ions, and the resulting high pH value. Siqueira et al (1999) proposed that the lethal effect of calcium hydroxide on bacterial cells is probably due to the hydrolysis of bacterial cell membrane components, such as the destruction of the phospholipid of the cellular membrane and the disruption of enzymatic activities and structural protein. Calcium hydroxide is also thought to cause splitting of DNA strands so that cell replication is affected.

For complete disinfection of the dentine, the locally applied medications must penetrate into the dentine at a concentration high enough to kill the invading bacteria. To retain its antibacterial activity, the disinfectant must also resist inactivation by dentine and its various organic and inorganic components, such as inflammatory proteins and pulpal remnants (Portenier et al. 2002). In the case of calcium hydroxide, the pH value in the root canal may be greater than 12.2, but in the most peripheral dentine, the pH ranges from 7.4 to 9.6 (Tronstad et al. 1981). Nerwich et al (1993) reported that the pH level of the outer dentine at both the cervical and apical level was low, reaching 9.3 and 9 respectively, after two weeks. Portenier et al (2001) showed that the antimicrobial effect of calcium hydroxide on *E. faecalis* was variably inhibited by the presence of dentine,

hydroxyapatite, and serum albumin. Therefore, some authors (Dahlen et al. 2000; Molander et al. 1998) have raised concerns that bacteria such as *E. faecalis* may survive in a root canal filled with calcium hydroxide because of the buffering effect of dentine against alkaline pH. Nonetheless, calcium hydroxide remains the medicament of choice at present for the treatment of infected teeth with chronic apical periodontitis. In a recent *in vivo* study in dogs, histological examination of teeth filled with bacterial endotoxins showed a marked inflammatory infiltrate and extensive areas of alveolar resorption, whereas the periapical tissues in 18 of the 20 roots filled with endotoxins and calcium hydroxide had a normal histological appearance (Silva et al. 2002). This observation is in agreement with Barthel et al (1997) and Safavi et al (1993) who reported that calcium hydroxide hydrolyses Lipid A, a major component of bacterial lipopolysaccharides (endotoxins), rendering them into non-toxic fatty acids and amino sugars.

It is well known that a small amount of formaldehyde is released during the setting reaction of the epoxy resin cement AH26 (Koch 1999; Spangberg et al. 1993). The antimicrobial and cytotoxicity of root canal sealer have been investigated in several studies (Kaplan et al. 1999; Weiss et al. 1996). Another approach to eliminating any remaining micro-organisms would be the complete obturation of the cleaned and disinfected root canal. In this way, the remaining micro-organisms may be killed by the more slowly acting antimicrobial effect of the sealer, or by the zinc ions released from gutta percha.

The development of Photoactivated Disinfection (PAD)

In view of the resistance of many organisms to conventional antimicrobial regimens, the use of light activated antimicrobial agents represents an alternative approach to killing bacteria. It has long been recognized that many bacteria can be killed by exposure to UV light whereas the viability of most species is largely unaffected by light in the visible region of the electromagnetic spectrum. The consequences of irradiating micro-organisms with laser light is dependent on the characteristics of the organism and the incident light, and the environment in which the interaction take place. Exposure of bacteria to high power laser energy will usually result in the death of the bacteria from photothermal, photoablative and photomechanical effects.

In contrast to high power lasers, the energy dose delivered by low power lasers is usually less than one joule at an energy density of only several J/cm^2, therefore any effects resulting from the irradiation of living organisms with low-level laser light are invariably photochemically induced and not photothermal in nature. The development of photodynamic therapy may be traced to the work in the late nineteenth century by Robert Koch and Paul Ehrlich (as cited in Wainwright et al. 2002) who began to use different dyes to stain different cellular structures. Ehrlich then observed that it was possible to stain microbial species *selectively*, and that some of these dyes were able to inactivate the stained microbes. Lethal photosensitisation by means of antimicrobial or cytotoxic activities of photosensitiser with an application of light energy was first demonstrated nearly one hundred years ago by Raab (as cited in Millson et al. 1996). Subsequently, Gram positive bacteria, Gram negative bacteria, mycoplasma, yeast, and viruses have all been shown to be susceptible to killing by visible light after treatment

with an appropriate photosensitizer (Malik et al. 1990; Mohr et al. 1997; Wainwright 2002; Wilson et al. 1993b). While photodynamic antimicrobial chemotherapy has traditionally been primarily concerned with the disinfection of whole blood and blood products, its strength lies in eradication of topically localized infections, in which oral infections of the hard and soft tissues are well-suited.

A range of photosensitisers has been investigated for use with different laser wavelengths. Okamoto (1992) noted that lethal photosensitisation with a HeNe laser could be obtained with ten kinds of blue, purple and green dyes, mainly in the phenylmethane family. The selection of an effective photosensitiser is essential for the success of this technique. As well as having a photosensitiser that is non-toxic to human cells, the ideal photosensitiser must be able to absorb strongly at the wavelength of the light used, have a high excitation efficiency (a high probability of triplet state formation per photon absorbed) and a relatively long lived (several microseconds) triplet state (MacRobert et al. 1989). By matching the absorption peak of dye to the wavelength of the laser system, Wilson (1997) commented on the possibility of using a combination of dyes with different degrees of absorption at a particular wavelength to achieve different effects at different depths.

The underlying principle of photodynamic antimicrobial actions has been reviewed in detail by Wainwright (1998). When an aromatic molecule (the photosensitiser) absorbs light energy, it may undergo an electronic transition to the singlet excited state. Depending on the molecular structure and the environment, the photosensitiser molecule may then lose its energy and return to the ground state, or it may undergo a transition to the triplet excited state. At the triplet excited state, the photosensitiser molecule may undergo a redox reaction with its environment, transfer its energy to

molecular oxygen leading to the formation of the labile singlet oxygen, or again return to the ground state (Figure 1).

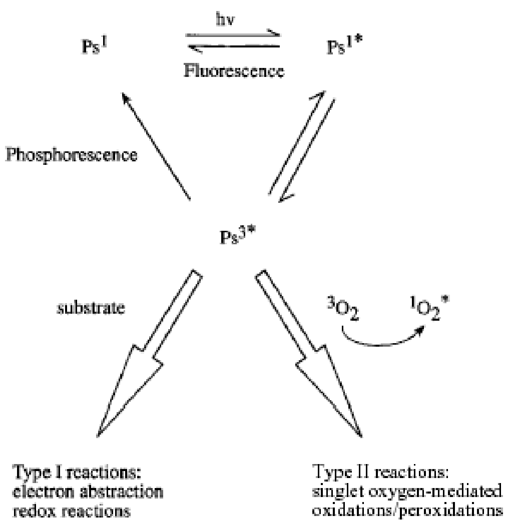


Figure 1. From Wainwright (1998). Ps^1: photosensitiser. Ps^{1*}: singlet excited state photosensitiser. Ps^{3*}: triplet excited state photosensitiser.

The ability of the photosensitiser molecule to instigate redox reactions or to form singlet oxygen depends on the production of a sufficient population of triplet state molecules. This in turn depends on the decay rate of both the triplet and the initially formed singlet states. For example, a highly fluorescent molecule which undergoes significant electronic decay from the excited singlet state would not be expected to form a high proportion of the triplet excited state.

By definition, photosensitisers are usually efficient in the formation of long-lived triplet excited states molecules. The light absorption characteristic of photosensitising compounds depends on their unique molecular structures. For example, furocoumarin photosensitisers (psoralens) absorb relatively high-energy ultraviolet (UV) light (at 300-

350nm), whereas macrocyclic, heteroaromatic molecules such as the phthalocyanines absorb lower energy, near-infrared light (at 700nm) (Table 2).

Photosensitiser type	λ_{max} range (nm)
Psolaren	300-380
Acridine	400-500
Phenazine	500-550
Cyanine	500-600
Porphyrins	600-650
Perylenequinonoid	600-650
Phenothiazinium	620-660
Phthalocyanine	660-700

Table 2. Photosensitiser absorption characteristics. Adapted from Wainwright (1998)

Mechanism and sites of lethal photosensitisation

Variations in microbial morphology will produce differences in photosensitiser localisation. Moreover, the time allowed for photosensitiser uptake before illumination may also be important. A photosensitiser that is taken up slowly by the micro-organism may at first cause only cell wall photodamage, whereas intracellular effects (such as nucleic acid strand breakage) will be apparent with longer incubation times.

At the molecular level, two types of photodynamic microbial damage have been recognised (Ochsner 1997). The Type I pathway involves electron transfer reactions from the photosensitiser triplet state to molecules other than oxygen, resulting in the formation of free radicals. These radical ions can then react with oxygen to produce cytotoxic species, such as superoxide, hydroxyl and lipid–derived radicals. Therefore, a Type I reaction with water in the microbial milieu can give rise to hydroxyl radicals (HO·), which then react with biomolecules or combine to give hydrogen peroxide *in situ*

with subsequent cytotoxic results. At the bacterial cytoplasmic membrane, Type I reactions with membrane phospholipid give rise to lipid hydroperoxide. The consequence is a loss of membrane integrity and fluid leakage. Because the other cell wall and cell membrane components such as aminolipids and peptides are also targeted, inactivation of membrane enzymes and receptors is possible.

The Type II pathways involve energy transfer from the photosensitiser triplet state to ground state molecular oxygen, to produce the excited state singlet oxygen, which can rapidly oxidize many biological molecules, such as polypeptides, nucleic acids and lipids, leading to cytotoxicity. The short half-life of singlet oxygen again ensures a localized response. Type II processes are generally accepted as the major pathways in photo-oxidative microbial cell damage. As with the Type I pathway discussed above, singlet oxygen will also react with molecules involved in the maintenance and structure of the cell wall and cell membrane (phospholipids, peptides, and sterols) (Girotti 1990). The amino acid, tryptophan undergoes cyclo-addition to become unstable intermediaries that affect peptide cross-linkages, while methionine residues may also react with singlet oxygen to produce methionine sulphoxide (Bonnett 1995). Reactions with nucleic acids occur mainly through guanosine. The Type I process is mediated via hydroxyl radical attack on the sugar moiety, whereas the Type II process is an attack of singlet oxygen on the guanine base (Foote 1990). The result is DNA strand breakage, leading to nuclear and mitochondrial disruption (Iwamoto et al. 1993; Schneider et al. 1990).

Site of action	Action	Result	Consequence	Cytotoxic event
Water	Hydrogen abstraction	Formation of hydroxyl radical	Formation of hydrogen peroxide, superoxide (O_2^-)	Further oxidative processes
Cell wall/membrane components	Peroxidation Oxidation of Tyr/Met/His residues	Peroxidation Protein degradation	Hydroperoxide formation Enzyme inactivation	Increased ion permeability Cell lysis
Respiratory chain	Redox reaction			Inhibition of respiration
Cytoplasmic enzymes	Oxidation Cross-linking			Inhibition of ribosome assembly
Nucleic acids residue (guanosine)	Oxidation of base or sugar	8-hydroxyguanosine	Nucleotide degradation Sugar degradation/cleavage	Strand cleavage Base substitution Mutation Inhibition of replication

Table 3. Reprinted from Wainwright (1998)

Cationic azine photosensitisers: Phenothiaziniums

In general, it is preferred that the photosensitiser selected for application in lethal photosensitisation (PAD) has a positive charge under physiological condition, since such photosensitisers are more readily taken up by the target microbes (Merchat et al. 1996). In addition, the photosensitiser chosen should be capable of absorbing laser light at the red end of the visible or near infrared spectrum. This is because such laser light will be better able to penetrate tissues surrounding a wound or lesion such as oral tissues and in particular, blood, which may be present at the sites to be treated (Lee et al. 1995; Odor et al. 1996).

Most oral bacteria do not contain any compounds exhibiting an appreciable absorption of low-level laser light which has a wavelength in the red or infrared red part of the spectrum. An exception is the black pigmented species belonging to the genera *Porphyromonas* and *Prevotella*, which contain protohaemin and protoporphyrin

respectively (Konig et al. 2000; Shah et al. 1979). Therefore, these pigmented micro-organisms such as *Prevotella* and *Porphyromonas* species may be susceptible to photoinactivation without the need for exogenous photosensitisers (Henry et al. 1996). Shah et al (1979) found that the protohaemin and protoporphyrin presented in *P. gingivalis* and *P. internedia* absorb strongly in the blue region, which explains why a low energy (70J/cm^2) irradiation from the Argon laser (at 488nm and 515nm) rapidly resulted in cell death (Henry et al. 1996). Wilson et al (1993b), however, reported that an 80 seconds exposure of HeNe laser at an energy dose of 584mJ and energy density of 44J/cm^2 had no effect on the viability of *P gingivalis.* In contrast, Konig et al (2000) reported a 41% reduction in the number of viable *P gingivalis* after exposure to red light from a HeNe laser at 100 mW/cm2 of light intensity and a fluence (energy density) of 360 J/cm^2.

In a search for the ideal photosensitiser, Wilson et al (1992) screened a number of compounds for their ability to sensitise oral bacteria to killing by low-level laser light from a HeNe laser. Sixteen of the compounds tested were able to act as a lethal photosensitiser of *S. sanguis*. These included toluidine blue O (tolonium chloride), methylene blue, aluminium disulphonated phthalocyanine (ADP), thionin, crystal violet and dihaematoporphyrin ester. Lethal photosensitisation could be achieved using energy densities of 1.1 - 33 J/cm^2, which was attained following an exposure time of between 2 to 60 seconds from a 7.3mW HeNe laser. Toluidine blue O and methylene blue were able to render periodontopathogenic species of *P. gingivalis*, *F.nucelatum,* and *A. actinomycetemcomitans* susceptible to killing by the HeNe laser light following exposure for 30 seconds (equivalent to an energy dose of 219mJ at a density of 16.5Jcm^2). However, the viability of these organisms was unaffected by the presence of

toluidine blue O and methylene blue (at 50μg/mL concentration) in the absence of laser light.

The susceptibility of a number of cariogenic species of bacteria to killing by low-level laser light in the presence of appropriate sensitisers was investigated by Burns and colleagues (1992; 1993). They found that *S.mutans, S. sobrinus*, *L. casei* and *A. viscosus* could be killed by exposure to light from either a 7.3mW HeNe laser after treatment with toluidine blue O, or a 11.0mW GaAs laser for 90 seconds after treatment with aluminium disulphonated phthalocyanine. In this investigation, the energy dose from the HeNe laser was 657mJ at an energy density of 50mJ/cm^2, while the parameters used for the GaAs laser were 990mJ and 1.5J/cm^2. Photo-inactivation of approximately 10^6 CFU were obtained for each organism. Further quantitative investigations showed that a large number of *S. sanguis* (10^6-10^7 CFU) could be killed by a 40 seconds exposure to a HeNe laser light (at energy dose of 292mJ and energy density of 22J/cm^2) in the presence of toluidine blue O, methylene blue and thionin (Wilson et al. 1993a).

The results observed by the Wilson group were also confirmed by other investigators. Using a 6mW HeNe laser to deliver an energy dose of 720mJ (energy density of 5.7 J/cm^2), Okamoto et al (1992) reported low-level laser light-induced killing of several species of sensitised cariogenic bacteria (mutans streptococcus) in the presence of dyes such as toluidine blue O or crystal violet. They also detected a significant decrease in the viability of a suspension of *S. sobrinus* following a 120s exposure to 3660mJ of HeNe light (energy density unspecified) in the presence of 8μg/mL crystal violet.

Caries, periodontal diseases and endodontic infections result from an accumulation of bacterial biofilm on the tooth surface. A biofilm consists of a dense cellular mass. It is

well-established that the behaviour of bacteria in biofilms can be very different from their behaviour in aqueous suspensions (Costerton et al. 1995). This is particularly so with regard to their susceptibility to antimicrobial agents. Dobson et al (1992) have shown that oral bacteria in biofilm can also be killed by low-level laser light in the presence of an appropriate photosensitiser. Killing of toluidine blue O or methylene blue-treated *S. sanguis, P. gingivalis, A. actinomycetemcomitans* and *F. nucleatum* was achieved following a 30s exposure to light from a 7.3mW HeNe laser.

Sensitiser	Organism			
	S. sanguis	*A. actinomycetem comitnas*	*F. nucleatum*	*P. gingivalis*
Toluidine blue O	+	+	+	+
Methylene blue	+	+	+	+
Aluminium disulphonated phthalocyanine	v	-	-	+
Dihaematoporphyrinester	-	-	-	+

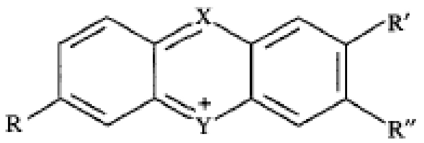
Table 4. Killing of oral bacteria in biofilm following a 30s exposure to light from a 7.3mW HeNe laser in the presence of various photosensitiser at a concentration of 50μg/mL. From Wilson (1994)

+: Bacterial killing detectable
-: No bactericidal effect detectable
v: Variable results obtained on different occasions

Lethal photosensitisation of the mixed bacterial population present in subgingival plaque has also been demonstrated *in vitro* (Sarkar et al. 1993). Samples of subgingival plaque taken from 20 patients with chronic periodontitis were exposed to low-level laser light from a 7.3mW HeNe for 30s (energy dose of 219mJ and energy density of 16.5J/cm^2) in the presence of 50μg/mL toluidine blue O. The counts of viable bacteria in the sample were reduced considerably by the dye and low-level laser light combination, but not by either the low-level laser light alone or dye alone. *P. gingivalis*

was eliminated from all the 14 samples in which it was detected, while black pigmented anaerobes were eliminated from 17 of the 18 samples in which they were present. *F.nucleatum* was eliminated from 11 of the samples, and the viable count reduced considerably in the remaining nine samples.

Methylene blue (MB) has been widely used as a histological stain for over a century. The phenothiazinium component of MB absorbs light strongly in the region 630-680nm, and has very little absorption elsewhere in the visible spectrum. Once light energy is absorbed, the electronically excited methylene blue is relatively stable and can undergo triplet state transition. This characteristic has attracted the attention of researchers in the field of photodynamic therapy, in the treatment of tumours and local antimicrobial disinfection (Wainwright & Crossley 2002). PAD using MB is now employed for inactivating viruses in fresh frozen plasma.



	R	R″	R′	X	Y	λ_{max} (nm)
Methylene blue	$(CH_3)_2N$	$N(CH_3)_2$	H	N	S	660
Toluidine blue O	$(CH_3)_2N$	NH_2	CH_3	N	S	625
Neutral red	$(CH_3)_2N$	NH_2	CH_3	N	NH	540
Proflavine	H_2N	NH_2	H	CH	NH	456
Acridine orange	$(CH_3)_2N$	$N(CH_3)_2$	H	CH	NH	492
Aminacrine	H	H	H	$C\text{-}NH_2$	NH	410
Ethacridine	H_2N	H	OC_2H_5	$C\text{-}NH_2$	NH	420

Table 5. Phenothiaziniums such as methylene blue (MB) and toluidine blue O (TBO) are blue dyes, which are closely related, with a simple tricyclic structure. From Wainwright (1998).

As illustrated in Table 3, **Toluidine blue O (TBO)** is closely related to methylene blue in its chemical structure. Toluidine blue O has been used as a redox indicator agent and an antiheparinic agent (Stringer 1999). In recent years, it has also gained increased usage in screening for oral mucosal malignant changes (Epstein et al. 2003; Onofre et al. 2001). TBO has also been reported to be an effective antifungal and antibacterial agent for inactivating yeast and a variety of Gram positive and Gram negative when it is used together with laser irradiation in PAD (Ito et al. 1977; Sarkar & Wilson 1993).

An area of concern which needs to be addressed in this discussion is that of host toxicity. The photosensitisers MB and TBO are known to be non-toxic in much higher concentrations than those required for effective pathogen killing with PAD. Both have been used in surgical procedures at much higher concentrations (normally at 1% w/v, equivalent to 1g/mL) without causing human toxicity (Sawyer et al. 1992). In terms of photodynamic antimicrobial chemotherapy, Soukos et al (1996) have shown that cell viability was not affected when cultures of human keratinocytes or fibroblasts were exposed to TBO (5.0µg/mL) and 2 minutes of laser irradiation from a 7.3mW HeNe laser (equivalent to 0.876J). In contrast, killing of *S. sanguis* was achieved following exposure to HeNe laser light for 75 seconds (0.547J) in the presence of 2.5µg/mL of TBO.

Clinical application of photoactivated disinfection in endodontics

Although *in vitro* studies of the use of low-level laser light to kill photosensitised oral bacteria have been encouraging, there has only been limited studies of its ability to kill micro-organisms *in vivo* in the root canal system. How useful PAD will be in endodontics will depend on whether it possesses advantages over current therapeutic modalities, and whether concomitant damage to adjacent host tissues can be avoided or minimised. The use of low-level laser light has advantages in that the bactericidal effect of PAD can be achieved without damaging the host tissues, and with little optical danger to the operator and patient. In addition, the hardware is inexpensive compared with high power lasers. While PAD could be undertaken as part of the routine disinfection of the root canal system, it may have the potential to be used as an additional antimicrobial regime in the eradication of persistent endodontic infection, for which conventional methods have been unsuccessful (Pinheiro et al. 2003; Sundqvist et al. 1998). The photosensitiser could be applied topically into the root canal system and a low-level laser light could be delivered using an optical fibre, for eradicating *E. faecalis* and other micro-organisms.

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Paper 2

Original Research

An *in vitro* comparison of four photoactivated disinfection systems using visible red light in the lethal photosensitisation of *E. faecalis* in root canals.

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Paper 2: Original research

Abstract

Aim: The aim of this study was to examine the bactericidal effects exerted by visible red lasers (635 and 670 nm) and red light emitting diodes (630 and 670 nm) on *E. faecalis* in the presence or absence of photosensitisers.

Methodology: 93 extracted teeth with single canals were selected. The root canals were prepared with Gates Glidden burs and rotary nickel titanium instruments to an apical size of 0.35mm. The roots were then randomly divided into groups of five teeth and autoclaved.

The root canals in each group were then inoculated with 10 μL of planktonic *E. faecalis* (equivalent to MacFarland Standard 1) and equal volumes of sterile PBS (negative control), 1% Milton (positive control), 100μg/mL methylene blue (MB), and 100μg/mL toluidine blue O (TBO) and left for 120s.

The photoactivated disinfection groups consisted of an additional nine groups of root canals inoculated with 10uL of planktonic *E. faecalis* and equal volumes of sterile PBS, 100μg/mL of methylene blue (MB), 100μg/mL toluidine blue O (TBO) and 13μg/mL TBO. These roots were then exposed to visible light irradiation of 120s from a 670nm LED or 670nm laser, or a 630nm LED or 635nm laser respectively.

The surviving bacteria were enumerated by viable counting following 24 hours of aerobic incubation at 37ºC.

Results: The combination of MB or TBO with 120s exposure of laser energy caused a significant reduction (2 $\log_{10}$) in the number of viable bacteria. A moderate reduction in the number of viable bacteria was also observed with LED lights in the presence of photosensitisers. However, treatment with photosensitisers alone or light alone produced minimal effect. No viable bacteria could be recovered following treatment with 1% NaOCl.

Conclusion: The combined use of a photosensitising agents and a low power laser was bactericidal to planktonic *E. faecalis* in root canals but was unable to achieve total sterility.

Keywords: laser, photosensitiser, root canal, *Enterococcus faecalis.*

Introduction

Micro-organisms play a crucial role in the development of pulpal and periapical disease (Kakehashi et al. 1965). Therefore, elimination of infection from the root canal system is the ultimate goal of endodontic treatment. Teeth that are treated according to accepted clinical principles usually have a good healing response, with most follow-up studies on endodontic therapy reporting overall success rates between 85% and 90% (Grahnen et al. 1961; Sjogren et al. 1990; Strindberg 1956).

Although many failed cases are caused by technical problems during treatment, some cases fail even when apparently well treated. A number of factors have been identified as agents associated with failure of endodontic therapy. These include extra-radicular infection, foreign body reactions and true cysts (Siqueira 2001). However, most treatment failures are caused by micro-organisms persisting in the apical part of the root canal of obturated teeth. Studies of the microbial flora from the canals of previously root filled teeth with persisting periapical infection have revealed that the flora differs markedly to that of untreated necrotic dental pulp (Chavez De Paz et al. 2003; Molander et al. 1998). The genera most frequently implicated as persistent pathogens are non-mutans *Streptococci*, *Enterococci*, *Staphylococci*, *Fusobacteria*, *Peptostreptococci* and *Lactobacilli* (Chavez De Paz et al. 2003; Spratt et al. 2001).

Numerous clinical studies have sought to evaluate the antimicrobial effectiveness of treatment strategies. Mechanical instrumentation alone does not appear to reduce the bacterial load effectively or permanently (Bystrom et al. 1981), so the use of antimicrobial agents for irrigation and medication of root canals is necessary to further reduce the level of bacteria (Bystrom et al. 1985a; Bystrom et al. 1983; Bystrom et al.

1985b). However, these studies also demonstrate that, despite the use of such antimicrobial agents, bacteria persist within the root canal space. Several studies have reported that *Enterococcus faecalis* appears to be highly resistant to conventional antimicrobial agents used during treatment, such as the alkaline pH of calcium hydroxide (Estrela et al. 1999; Evans et al. 2002). Once established in the root canal, *Enterococcus faecalis* is difficult to remove (Dahlen et al. 2000).

New approaches to eliminating the infection from root canal systems include the non-instrumented technique (Lussi et al. 1995) and the use of laser technology (Kimura et al. 2000). A key problem in achieving a total kill of bacteria in root canals is that the antimicrobial agent may not have access to the bacteria because of anatomical barriers. A common property of these new techniques is that anatomical complexities do not pose the same barriers. Laser light shone on the crown surface could potentially be redirected in multiple directions by virtue of its transmission through enamel prisms and dentinal tubules, which effectively acts as fibre optic channels (Odor et al. 1996). High power lasers such as the CO_2 (Zakariasen et al. 1986), Nd:YAG (Ramskold et al. 1997), Er:YAG (Mehl et al. 1999) and diode (Moritz et al. 1997) have been used for disinfection of the root canals. The antibacterial effects of these lasers are a function of dose-dependent heat generation. The amount of heat delivered has undesirable effects such as charring and cratering of dentine, resorption and ankylosis of roots, and periradicular necrosis (Bahcall et al. 1992; Hardee et al. 1994; Ramskold et al. 1997; Turkmen et al. 2000). These disadvantages may however, be overcome by sensitising the micro-organisms with a photosensitive agent that can release bactericidal radicals when stimulated by light of an appropriate wavelength. This is termed photoactivated disinfection (PAD).

Photoactivated disinfection is a technique for killing cells with visible light after pre-treatment with photoactive compounds known as photosensitisers. Photosensitisers such as methylene blue and toluidine blue O are similar in chemical structure, and both exhibit similar physico-chemical properties. They have little or no antimicrobial activity on their own, however, excitation of the photosensitiser in an appropriate wavelength of light will result in the formation of radical oxygen species.

The aim of this study is to compare the *in vitro* efficacy of four different PAD systems on *Enterococcus faecalis* in root canals. The four PAD systems consist of matched combinations of (1) toluidine blue O photosensitiser and 635nm red visible laser, (2) toluidine blue O photosensitiser and 630nm red visible LED light, (3) methylene blue photosensitiser and 670nm red visible laser, and (4) methylene blue photosensitiser and 670nm red visible LED light.

Material and Methods

This study followed a matrix design as follows, with 13 groups in total: 2 groups for each laser type and 4 control groups. These controls account for the effect of sham irradiation, the effect of 0.5% NaOCl (positive control) and the effect of photosensitisers without laser irradiation. The photoactivated antimicrobial activity of 13µg/mL toluidine blue O solution in combination with the Savedent 635nm laser (Denfotex, Inverkeithing, United Kingdom) was also studied. The toluidine blue O photosensitiser at this concentration was of particular interest as it was supplied and intended to be used with the Savedent 635nm laser.

	Rationale					
Control	Baseline and background kill	PBS (pH 7.2)	Milton (Diluted to 0.5%)	TBO (50µg/mL)	MB (50µg/mL)	
Laser Alone	Baseline kill by laser alone	LED670	Omnilase670	LED630	SD635/50	
		PBS	PBS	PBS	PBS	
PAD	PAD killing	LED 670	Omnilase670	LED630	SD635/50	SD635/13
		MB	MB	TBO	TBO	TBO

Preparation of the root canals for bacterial sampling

The experimental model consisted of a series of single root canals standardised in preparation and volume. Teeth that were extracted for restorative reasons were immediately stored in 1% sodium hypochlorite. The roots of the teeth were then separated from the crowns by sectioning at the cemento-enamel junction. Extracted teeth were used in preference over impermeable tubes (such as a test tube) to replicate the penetration of laser light seen *in vivo* (Gazelius et al. 1988; Olgart et al. 1988).

The individual root canals were then prepared using a crown down technique (Buchanan 2000) to an apical size of 35 with GT (Dentsply Tulsa Dental, Tulsa, USA)

and ProFile (Dentsply Maillefer, Ballaigues, Switzerland) rotary nickel titanium (NiTi) files. These files were driven with a torque-controlled handpiece unit (ATR Tecnika, Pistoia, Italy). Between each instrument change, the root canals were thoroughly irrigated with 1% sodium hypochlorite (Milton, Procter & Gamble, Parramatta, Australia) and 15% EDTAC (The Mill Pharmacy, Brisbane, Australia) in an alternating sequence (Abbott et al. 1991; Yoshida et al. 1995). Finally, the root canals were enlarged with Gates Glidden burs #4-6 (Denstply Maillefer, Ballaigues, Switzerland). The amount of dentine to be removed was pre-calculated (Appendix 1), such that the root specimens could contain a standard volume of 20μL. The root specimens were then sterilized by autoclaving at 121ºC for 15 minutes, and stored in a sterile container at 100% humidity. For each of the 13 groups, there was a minimum of five replicates, giving a total of 93 samples.

Bacteria used in the experiment

The bacterial species used to investigate the efficacy of photoactivated disinfection was selected based on specific characteristics. *Enterococcus faecalis* has been implicated as an aetiological organism in non-resolving endodontic lesions (Sundqvist et al. 1998), and hence is of major interest in the microbiological management of the root canal space.

A freeze dried culture of *Enterococcus faecalis* was obtained from the repository at the Department of Oral Biology, the University of Queensland, and grown on trypticase soy agar (TSA) plates (Acumedia, Baltimore, USA). Aerobic culturing conditions at 37ºC

were used for this study as *Enterococcus faecalis* is a facultative organism. The purity of the bacteria culture was checked by Gram staining and colonial morphology.

In the experimental model, a stock suspension of *E. faecalis* was prepared to a turbidity equivalent of MacFarland Standard 1 by direct visual comparison with a known standard (MacFarland Standard 1, equivalent to 300 x 10^6 CFU/mL).

Laser and LED light Specifications

The following laser parameters were used:

- InGaAs diode laser, 635nm, 100mW continuous wave, 120 seconds exposure, with a 400µm side-dispersing optical fibre (Savedent, Denfotex, Inverkeithing, United Kingdom).
- InGaAsP diode laser, 670nm, 50mW continuous wave, 120 seconds exposure, with a 400µm optical fibre (Omnilase, Laserdyne, Ernest Junction, Australia).
- LED light, 630nm and 670nm, 5mW continuous wave, 120 seconds exposure, with a 400µm optical fibre (PhotonForce 5, Laserdyne, Ernest Junction, Australia).

Photosensitisers and other reagents

The following photosensitisers were used: Toluidine blue O (Sigma Chemicals, St. Louis), and Methylene blue (BDH Chemicals Ltd., Poole). Stock solutions of TBO and MB were prepared at a concentration of 100µg/mL, in filtered-sterilized phosphate buffered saline. This gave a concentration of 50µg/mL when the photosensitiser was

mixed with the stock solution of *Enterococcus faecalis* in PBS in the experimental model.

Sodium hypochlorite solution obtained commercially in an airtight opaque bottle (Milton, 1% sodium hypochlorite, Procter & Gamble, Parramatta, Australia) was used in the experimental model without alteration. This gave a concentration of 0.5% when the sodium hypochlorite was mixed with the stock solution of *Enterococcus faecalis* in PBS.

Experimental model

Enterococcus faecalis was used in planktonic form by harvesting well-separated colonies from TSA (trypticase soy agar) plates, and suspending the bacterial cells in filter-sterilized phosphate buffered saline. The cell numbers in the suspension were adjusted to 3 x 10^8 CFU/mL using MacFarland Turbidity Standard (BioMerieux) by direct visual comparison with these known standards.

During the experiment, equal volumes of planktonic *Enterococcus faecalis* and photosensitiser/control solutions were freshly mixed in a vial and 20µL of this mixture was then aspirated and inserted into the root canal by fine needle micropipette. The length of the laser fibre was pre-determined by using a standard endodontic instrument stopper (Progress, Gunz Dental, Australia) which was placed at a distance of 2mm into the root canal space. The inoculated root canals were then irradiated for a total of 120 seconds. Following withdrawal from the canal, the fibre was disinfected with 70% alcohol to prevent cross contamination. The time taken to mix the bacteria with the

photosensitiser/control solution was less than two minutes, and each specimen received a similar period of exposure to the photosensitiser prior to laser irradiation.

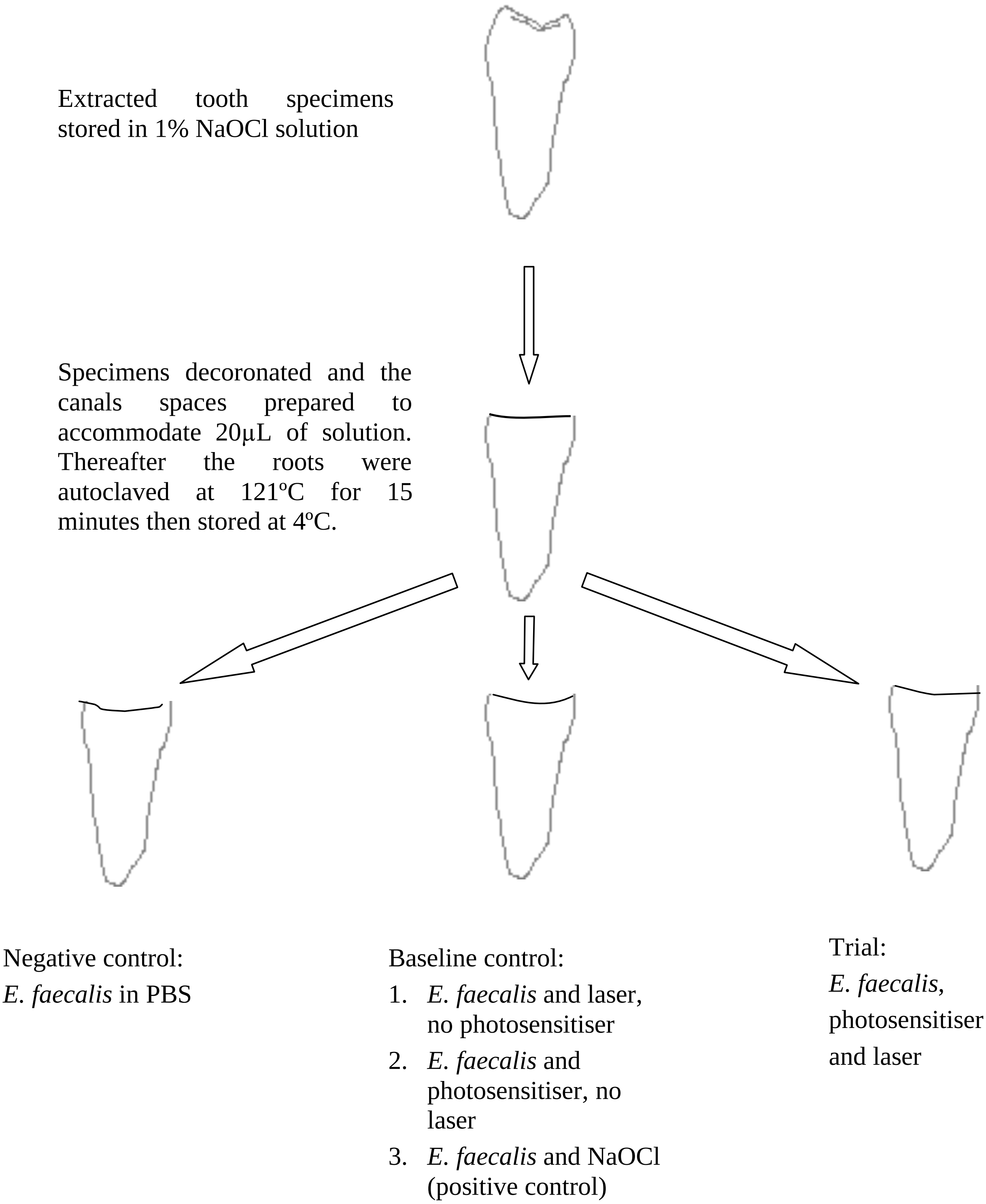
To assess the baseline viable cell number in the planktonic suspension, the *Enterococcus faecalis* suspension was diluted with an equal volume of phosphate buffered saline and sham irradiated for 120 seconds. Baseline killing by methylene blue or toluidine blue O alone was also determined in a similar fashion. In addition, the killing effect of 1% Milton solution was assessed so that the efficacy of various photoactivated disinfection (PAD) systems could then be compared to existing endodontic disinfecting regimes (Bystrom & Sundqvist 1983; Siqueira et al. 1997).

Immediately after laser or sham treatment (laser alone), the root canals were sampled by aspirating 5μL of the treated fluid from the root canal by means of a fine needle micropipette. The fluid was placed into a 5mL sterile vial containing 495μL of filtered-sterilized PBS to provide an initial dilution of 1 in 100. A dilution series (1:1,000 to 1:100,000) was prepared by transferring 100μL to 900μL of filtered-sterilized PBS (Appendix 4). For each dilution, the solution was vortex mixed for a period of 15 seconds, and 50μL volume from each vial in the dilution series was then plated out onto TSA plates, which were incubated for 24 hours at 37ºC in an aerobic cabinet. Following incubation, the number of bacterial colonies (colony forming units, CFUs) on each plate was determined by manual counting.

Assessment of thermal changes during PAD

To assess thermal changes at the root surface, thermocouples placed at the coronal (zone 1) and middle (zone 2) thirds of the tooth and held in place with heat-conductive compound were connected to a computerised thermal recording station. This arrangement allowed thermal data to be recorded at one second intervals for the duration of the laser treatment. The thermal data for each group (temperature increase and cooling time in each of the two zones) was then expressed as a range from the baseline temperature at a time = 0 second.

Schematic of experimental design



Analysis of results

This study was conducted in a series of three separate experiments. Variations in the bacterial load in each root canal were expected, because of inherent errors in the production of the bacterial suspensions and in sampling. Therefore, in order to make valid comparisons between each of the experimental runs where *Enterococcus faecalis* was subjected to various treatment regimes, the data was expressed as a percentage of baseline viable cell numbers (percentage kill rate). The killing effect was also expressed on a log scale using base 10 such that a 99% kill would be expressed as a 2.0 log kill.

For quantitative statistical analysis, the mean percentage kill rates and the respective standard deviations were analysed using One-way Analysis of Variances (ANOVA) with Bonferroni correction for multiple comparisons between subgroups. Using this approach, it was possible to compare the effect of PAD (PAD using various parameters) to the effect of laser/LED alone and photosensitiser alone.

To obtain a direct comparison of the various PAD systems, an additional separate experiment was undertaken in which each PAD therapy could be conducted simultaneously.

Results

Effect of sodium hypochlorite (positive control for killing)

No viable bacteria (100% kill, equivalent to 2 $\log_{10}$ kill rate) could be recovered from any teeth inoculated with the *Enterococcus faecalis* broth and treated with 1% sodium hypochlorite (0.5% w/v) for 120 seconds. This result was consistently observed in all five samples tested.

Effect of toluidine blue O alone

There was a small reduction (13%) in the number of viable bacterial cells following 120 seconds exposure to the 50µg/mL toluidine blue O dye. This represents a 1.10 $\log_{10}$ kill compared to the baseline count.

Effect of methylene blue alone

There was a mild reduction (28%) in the number of viable bacterial cells following 120 seconds of exposure to the 50µg/mL methylene blue dye. This represents a 1.45 $\log_{10}$ kill compared to the baseline cell number.

Effect of 630nm and 670nm LED light alone

Exposure of the *Enterococcus faecalis* to 120 seconds of 630nm LED light resulted in a minimal reduction (3.97%) in the number of viable bacterial cells. This represents a reduction of 0.60 $\log_{10}$ compared to the baseline cell number. A greater reduction (12.6%) in the viable bacterial cell number was observed following 120 seconds of

exposure to the 670nm LED light. This represents a reduction of 1.10 $\log_{10}$ compared to the baseline cell number.

Effect of 630nm Savedent laser alone

Exposure of the *Enterococcus faecalis* to 120 seconds of 630nm laser light resulted in a 15.2% reduction in the number of viable bacteria cells. However, this represents only a 1.18 $\log_{10}$ reduction compared to the baseline cell number.

Effect of 670nm Omnilase laser alone

Exposure of *Enterococcus faecalis* to 120 seconds of 670nm laser light resulted in a 5.6% reduction in the number of viable bacteria cells. This represents only a 0.75 $\log_{10}$ reduction compared to the baseline cell number.

Effect of 630nm LED/toluidine blue O PAD system

The combined effect of 630nm LED light and 50μg/mL toluidine blue O photosensitiser resulted in a no reduction in the number of viable bacteria cells. Indeed, the results showed an average of 11% (equivalent to 1.04 $\log_{10}$) increase compared to the baseline cell number, which may be due to sampling error.

Effect of 635nm Savedent laser/toluidine blue O PAD system

The combined effect of 635nm laser light and 50μg/mL of toluidine blue O photosensitiser resulted in an average of 92.2% reduction in the number of viable bacteria cells. This represents an average of 1.96 $\log_{10}$ reduction compared to baseline cell numbers. In contrast, the combination of 635nm laser and 13μg/mL toluidine blue

O as supplied with the Savedent laser unit, achieved a reduction of 76.5% and a 1.88 log_{10} reduction compared to the baseline cell number.

Effect of 670nm LED/methylene blue PAD system

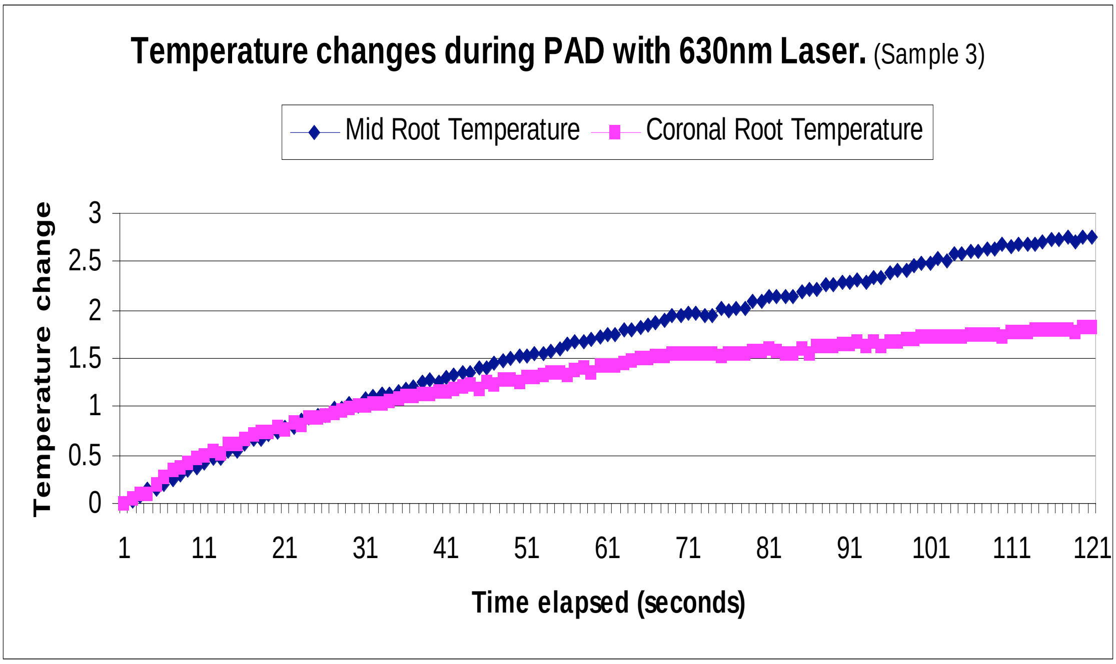
The combined effect of 670nm laser light and 50µg/mL methylene blue photosensitiser resulted in an average of 84.0% reduction in the number of viable bacteria cells. The results showed an average of 1.92 log_{10} reduction compared to the baseline cell number.

Effect of Omnilase/methylene blue PAD system

The combined effect of 670nm laser light and 50µg/mL of methylene blue photosensitiser resulted in an average of 97.0% reduction in the number of viable bacteria cells. This is an average of 1.99 log_{10} reduction compared to the baseline cell number.

Temperature changes during PAD

The maximal thermal change occurred when the 630nm laser/toluidine blue O photosensitiser combination was used for photoactivated disinfection. This corresponded to a temperature rise of 2.74ºC. All other PAD systems recorded a much lower rise in temperature (Appendix 10).



Statistical analysis

The mean percentage kill rates and the respective standard deviations were analysed using One-way ANOVA with Bonferroni correction for multiple comparisons between subgroups. The statistical analysis confirmed the trend noted in the qualitative assessment.

In Experiment 1 (Appendix 9.1), there was no statistical difference between the mean percentage kill for the specimens in the LED 670 alone, Omnilase 670nm alone and MB alone groups but all three regimes were significantly different from the specimens that were treated using PAD with LED 670nm or PAD with Omnilase 670nm ($p<0.001$). No statistical difference was detected between the effects of PAD with LED 670nm and PAD with Omnilase 670nm.

The results from Experiment 2 (Appendix 9.2) were similar, there was no statistical difference between the mean percentage kill for the specimens in the LED 630 alone, Savedent 630nm alone and TBO alone groups but all three regimes were significantly different from the specimens that were treated using PAD with Savedent 635nm/50μg/mL TBO ($p<0.001$). PAD with Savedent 635nm/50μg/mL TBO was significantly ($p<0.001$) more effective than PAD with LED 630nm. PAD with LED 630nm did not appear to be more effective at disinfecting planktonic *E. faecalis* compared to treatment with LED 630nm alone ($p>0.05$).

In Experiment 3 (Appendix 9.3), PAD with LED 630nm was significantly less effective in disinfecting planktonic *E. faecalis* compared to PAD with Omnilase 670nm, Savedent 635nm/50μg/mL and Savedent 635nm/13μg/mL ($p<0.001$). No statistical difference was detected between the mean percentage kill for the specimens treated using PAD with Omnilase 670nm, Savedent 635nm/50μg/mL and Savedent 635nm/13μg/mL. However, there was a trend towards a more consistent and greater reduction in CFU for the specimens that were treated with Savedent 635nm/50g/mL, compared to Savedent 635nm/13μg/mL.

Summarizing the results of statistical analysis,

(1) PAD with LED 670nm and Omnilase 670nm were statistically superior to the effects of methylene blue photosensitiser alone, red visible light or laser (670nm) alone in sanitising the infected root canal specimens.

(2) PAD with Savedent 630nm was statistically superior to the effects of toluidine blue O photosensitiser alone, red visible light (630nm) or laser (635nm) alone in sanitising the infected root canal specimens.

(3) PAD with LED 630nm was statistically inferior to the effects of PAD with LED 670nm, Omnilase 670nm and Savedent 635nm in sanitising the infected root canal specimens.

(4) There was no statistical difference in the efficacy of photoactivated disinfection when Savedent was used, either with 50µg/mL concentration or 13µg/mL concentration of TBO. However, the general trend in the raw data suggested a consistently higher kill rate when the Savedent laser was used in combination with 50µg/mL of TBO.

Therefore, the quantitative and qualitative analysis indicates that there are significant and independent effects of the type of light source and dye (photosensitiser) concentration, on the PAD killing effect. Overall, there was no statistical difference between the MB and TBO based PAD systems even though there was a consistent trend across all three experiments of slightly higher kill rate with the TBO based PAD system but a more consistent kill rate with the MB based system.

Discussion

A low power laser in itself is not particularly lethal to bacteria, however PAD techniques use a low power laser to elicit a photochemical reaction. To this end, PAD can be optimized by matching laser wavelength to the peak absorption of the photosensitiser and allowing sufficient time for the photosensitiser to be absorbed into the bacteria cells. Previous studies into lethal photosensitisation have shown that Gram positive bacteria, Gram negative bacteria, fungi and viruses are all susceptible to killing by PAD (Malik et al. 1990; Mohr et al. 1997; Wainwright 2002; Wilson et al. 1993). The potential of PAD as a treatment for localized microbial infections has been laboratory tested on planktonic micro-organisms associated with carious lesions (Burns et al. 1993; Burns et al. 1995; Stringer 1999), periodontal disease (Dobson et al. 1992; Sarkar et al. 1993; Wilson et al. 1992; Wilson et al. 1993), and root canal infection (Seal et al. 2002; Silbert 1999). PAD has been shown to kill bacteria in biofilm, such as subgingival plaque, which is typically resistant to the action of commonly available antimicrobial agents (Dobson & Wilson 1992).

Silbert (1999) has shown that planktonic broths of both *S. mutans* and *E. faecalis* are susceptible to lethal photosensitisation by the effect of red visible laser light after treatment with methylene blue. However, he reported *E. faecalis* to be more resistant to killing compared to *S. mutans*. Moritz (2000) suggested that the resistance of *E. faecalis* to laser exposure may be explained by its thick cell wall structures, compared to other Gram positive bacteria.

In this investigation, planktonic *Enterococcus faecalis* in root canals was irradiated with light energy from two different lasers and two different LED lights after sensitizing the *Enterococcus faecalis* with an appropriate photosensitiser. *Enterococcus faecalis* was chosen as the test organism because it has been implicated in recalcitrant root canal infection, and several studies have showed it to be resistant to the effects of calcium hydroxide (Bystrom et al. 1985a; Molander et al. 1998).

In the methylene blue (MB) group, using the photosensitiser alone or sham irradiation alone resulted in a variable killing rate, but overall, the average log transformed kill values showed insignificant inactivation of *E. faecalis*. This data was in agreement with others (Burns et al. 1993; Dobson & Wilson 1992; Sarkar & Wilson 1993; Wilson et al. 1992; Wilson et al. 1993) who investigated the effects of HeNe laser on bacterial suspensions. In contrast, treatment of the planktonic *E. faecalis* with MB and light energy resulted in photoactivated disinfection but sterility was not achieved. The Omnilase diode laser in this treatment was more efficient than the LED light, which can be explained by the amount of energy being delivered to the root canal space.

In the toluidine blue (TBO) group, a similar pattern of results was obtained. TBO alone resulted in minimal inactivation of *E. faecalis*; low level light irradiation alone also proved ineffective in disinfecting the root canal space. The 630nm LED light used in

this study is probably not suitable for lethal photosensitisation of *E. faecalis* as no consistent bactericidal effect could be observed for this PAD system. However, the combination of the TBO and 635nm laser light was bactericidal to the *Enterococcus faecalis* broth. The 635nm diode laser was supplied with a lower concentration of toluidine blue O at 13µg/mL, however, toluidine blue O at this concentration was shown to be less effective against *E. faecalis* than toluidine blue O at a the higher concentration of 50µg/mL.

Summarizing the results of this investigation, planktonic *E. faecalis* was susceptible to photoactivated disinfection. A significant level of killing was observed with the following PAD systems:

(1) The combination of Omnilase 670nm diode laser and 50µg/mL MB and,

(2) The combination of Savedent 635nm diode laser and 50µg/mL TBO.

The results presented in this investigation are in contrast to Silbert's study (1999) where *E. faecalis* was shown to be somewhat resistant to photoactivated disinfection by the same 670nm Omnilase laser. However, this may be explained by the lower total amount of energy (10mW for 120 seconds, equivalent to 1.2J) being delivered to the planktonic bacteria, whereas 50mW at 120 seconds (equivalent to 6J) was delivered in the present study.

Cleaning, disinfection, and preparation of the root canal are indispensable requirements for successful endodontic treatment. Therefore, the combination of the mechanical preparation of root canals with irrigating solution that has proteolytic and disinfecting properties is well established. In this study, sodium hypochlorite was very effective against planktonic *E. faecalis*. The results of this investigation are not surprising and are

in agreement with other studies on the disinfecting quality of hypochlorite solutions on planktonic bacterial broth. For example, in his work on the effects on *E. faecalis* of a sub-lethal dose of sodium hypochlorite and calcium hydroxide, Evans et al. (2002) found that sodium hypochlorite could maintain antimicrobial activity against *E. faecalis* at concentrations as low as 0.0001%. Shih (1970) found that *Enterococcus faecalis* and *Staphylococcus aureus* were easily killed when incubated in a broth culture with low concentrations of sodium hypochlorite (0.0005%). However, in the same study, full strength sodium hypochlorite (5%) failed to eradicate the bacteria completely when an infected tooth model was used. The clinical significance of bacterial biofilm does not appear widely appreciated in endodontics until recently. For example, Sen (1999) found that 5% sodium hypochlorite was ineffective as an antimicrobial irrigant against an *in vitro* biofilm of *Candida albicans*. Most microbial infections in the body are caused by bacteria growing as a mono- or multi-species biofilm. Biofilms are microbial aggregates embedded in a matrix of extracellular polysaccharide on a solid surface. Compared to the planktonic counterparts, these biofilms can be up to 1500-fold more resistant to the effect of common antimicrobial agents (Spratt et al. 2001).

Lethal photosensitisation using a low power laser in a root canal infected with planktonic *E. faecalis* produced similar results to that reported for higher power laser systems (Nd:YAG, CO_2, Er:YAG). These laser systems achieved various degrees of bacterial killing but none were able to achieve sterility (Hardee et al. 1994; Le Goff et al. 1999; Mehl et al. 1999). There are several advantages of the application of PAD to the treatment of infected root canals. (1) PAD is able to effect a rapid and highly localized antimicrobial effect, (2) there is little likelihood of bacteria developing resistance, as PAD is mediated by singlet oxygen and free radicals and, (3) there are

minimal thermal side effects in the tissue surrounding the roots, a common feature associated with the use of high power lasers.

The maximum temperature rise during PAD was 2.74ºC. This occurred when the combination of the Savedent 635nm laser and TBO (50μg/mL) was used for 120 seconds. All other PAD systems recorded a much lower rise in temperature. For example, the greatest increase in temperature recorded for the other PAD systems was 0.54ºC (Appendix 10). The magnitude of this change would be considered negligible from a biological perspective. A general trend towards a greater temperature increase was observed for the middle third of the root compared to the coronal third. This is expected as the dentine thickness at the coronal third level is greater. The dentine acts as a thermal heat sink, thereby slowing the dissipation of thermal energy. Effectively, this resulted in a more gradual rise in the external root temperature, which was reflected in the recorded data for the duration of light irradiation (120 seconds). Clinically, the magnitude of thermal changes may be different to values indicated in this laboratory assessment. Laboratory testing was done on extracted teeth in an air-conditioned room whereas *in vivo* temperature rise is likely be lower due to the thermal inertia of the supporting tissues and thermal conductance of circulatory blood flow in the periodontium (Romero et al. 2000).

The efficacy of PAD is dependent on both the light energy dose delivered and the photosensitiser concentration employed. However, the ability of this technique to circumvent the complexities of root canal anatomy may be confounded by other factors. Whether this is caused by actual hindrance of light transmission, lack of penetration of photosensitiser or lack of generation and dispersal of free radicals remains unclear. Photoactivated disinfection in this study could not compete with NaOCl in achieving

consistent 100% bacterial kills. However, it is worth remembering that NaOCl has been shown to be not as effective as depicted here, such as in the treatment of polymicrobial infection (Bystrom & Sundqvist 1981; Bystrom & Sundqvist 1983).

The variations seen in bacterial killing with PAD may also be attributed to several limitations of the experimental model, which may influence the interpretation or application of the results of the study.

(1) Since this study investigated the killing efficacy of various PAD systems against a monoculture planktonic broth of *E. faecalis* in a single root canal, no conclusions can be drawn regarding the efficacy of PAD in the treatment of intra-canal bacterial biofilms. Further research is necessary to quantify the penetrative depth of lethal photosensitisation within dentinal tubules that open into the root canals. Previous research (Stringer 1999) has shown that PAD can be achieved in circumpulpal dentine for bacteria that has penetrated up to 1.5 mm into patent dentinal tubules.

(2) This experiment used a pure bacterial culture. While *E. faecalis* can be found as a mono-infection, infection in non-vital untreated teeth is typically polymicrobial in nature. Thus, a direct extrapolation of these results to all clinical situations is not possible.

(3) The small volume of samples may have introduced a degree of error within the subsequent quantification of the effects of PAD. While variation in the concentration of the initial inoculum may have introduced an additional error, this was accounted for by calculating ratios from the baseline. The requirements to obtain a sufficient volume from the canal space restricted the length of insertion of the laser optical fibre. This was necessary as displacement of solution from the canal by the laser optical fibre limited

the recovery of test samples required for culturing. The use of a smaller diameter fibre coupled with deeper penetration into the root canal space may increase the power density and hence the photochemical effect of the laser radiation.

Further studies will be required to establish the effectiveness of photoactivated disinfection in an *in vitro* biofilm environment and in clinical trials.

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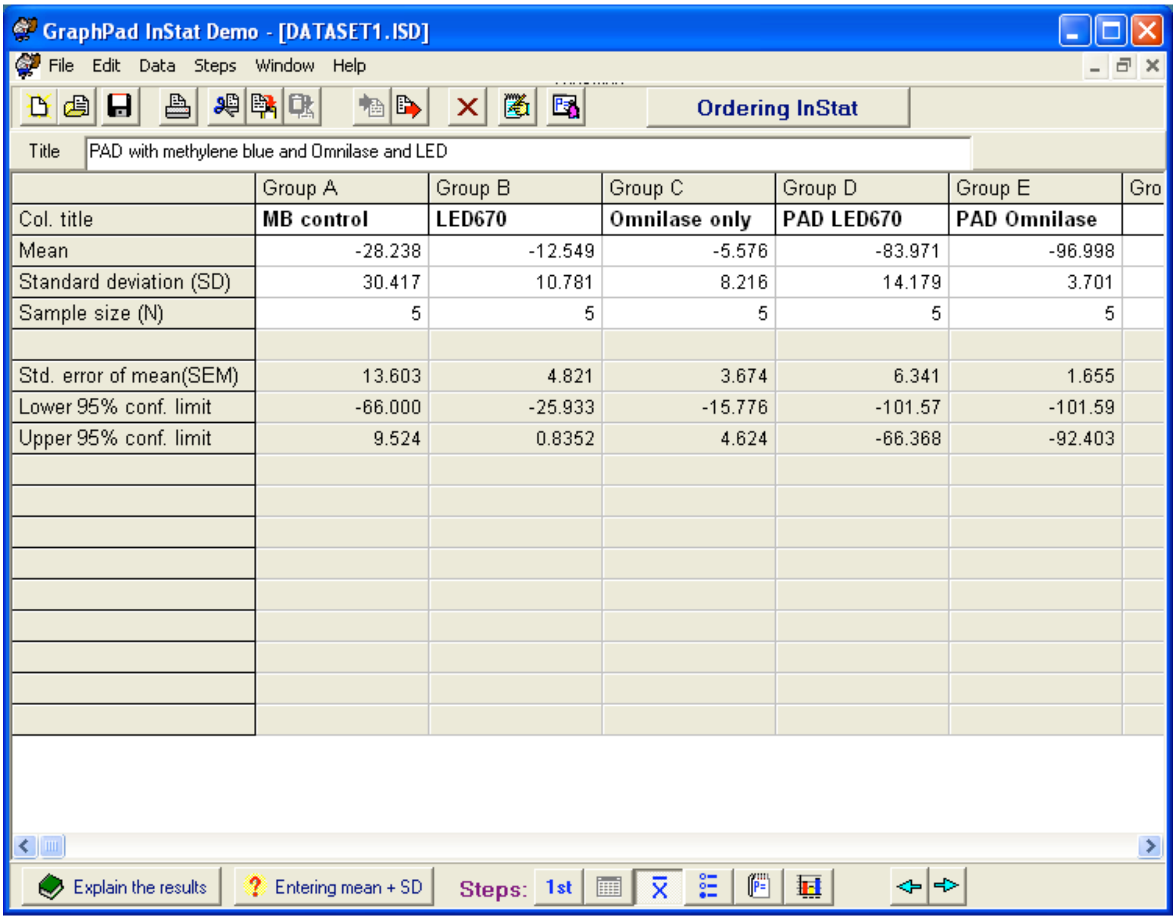
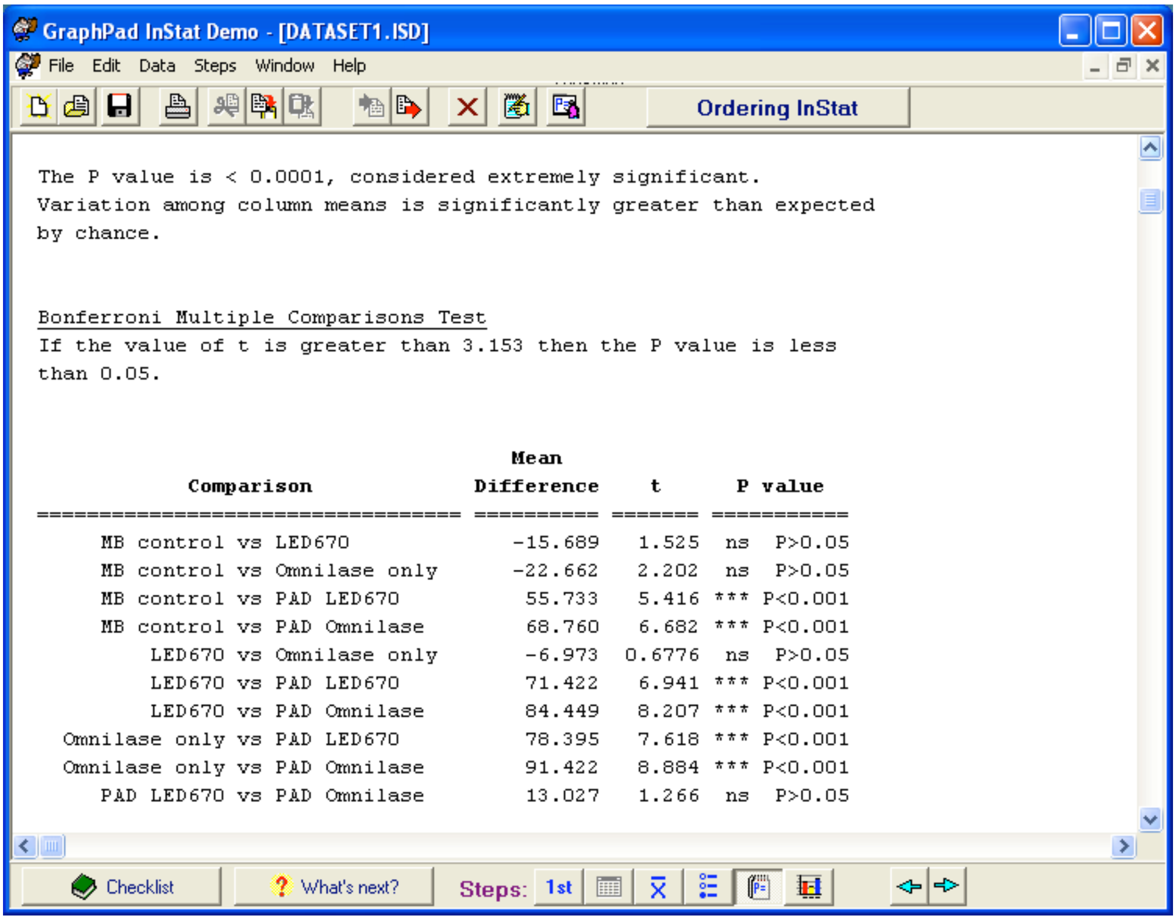


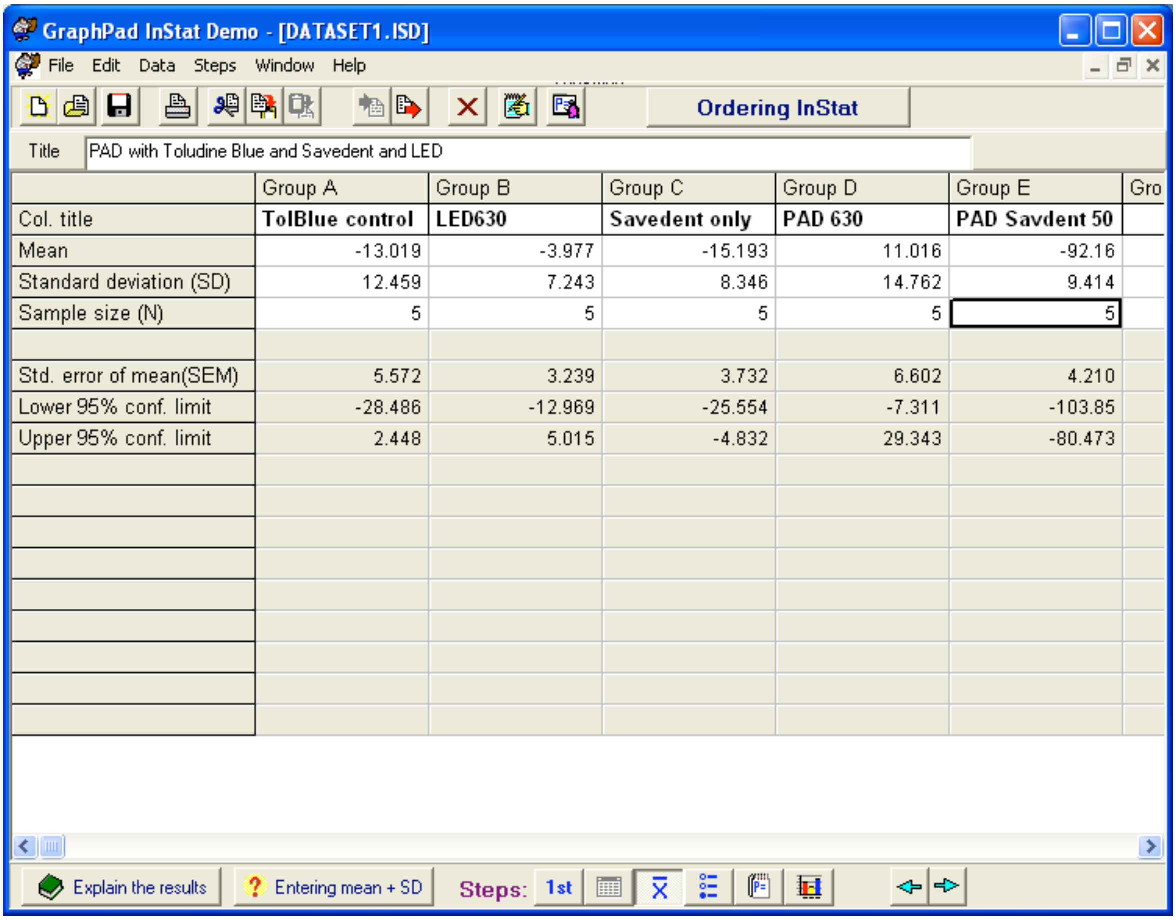
	Group A	Group B	Group C	Group D	Group E	Gro
Col. title	MB control	LED670	Omnilase only	PAD LED670	PAD Omnilase	
Mean	-28.238	-12.549	-5.576	-83.971	-96.998	
Standard deviation (SD)	30.417	10.781	8.216	14.179	3.701	
Sample size (N)	5	5	5	5	5	
Std. error of mean(SEM)	13.603	4.821	3.674	6.341	1.655	
Lower 95% conf. limit	-66.000	-25.933	-15.776	-101.57	-101.59	
Upper 95% conf. limit	9.524	0.8352	4.624	-66.368	-92.403	



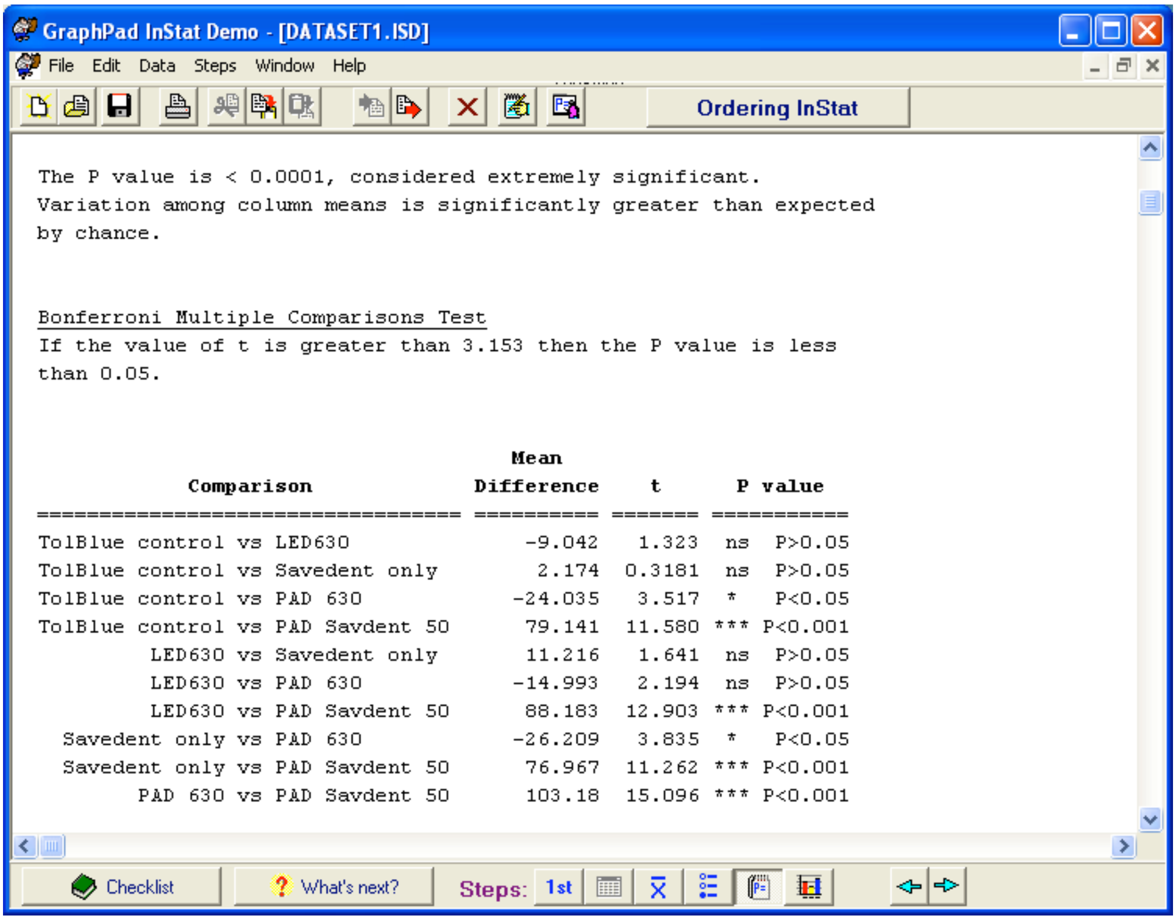
The P value is < 0.0001, considered extremely significant.
Variation among column means is significantly greater than expected by chance.

Bonferroni Multiple Comparisons Test
If the value of t is greater than 3.153 then the P value is less than 0.05.

Comparison	Mean Difference	t		P value
MB control vs LED670	-15.689	1.525	ns	P>0.05
MB control vs Omnilase only	-22.662	2.202	ns	P>0.05
MB control vs PAD LED670	55.733	5.416	***	P<0.001
MB control vs PAD Omnilase	68.760	6.682	***	P<0.001
LED670 vs Omnilase only	-6.973	0.6776	ns	P>0.05
LED670 vs PAD LED670	71.422	6.941	***	P<0.001
LED670 vs PAD Omnilase	84.449	8.207	***	P<0.001
Omnilase only vs PAD LED670	78.395	7.618	***	P<0.001
Omnilase only vs PAD Omnilase	91.422	8.884	***	P<0.001
PAD LED670 vs PAD Omnilase	13.027	1.266	ns	P>0.05



	Group A	Group B	Group C	Group D	Group E	Gro
Col. title	TolBlue control	LED630	Savedent only	PAD 630	PAD Savdent 50	
Mean	-13.019	-3.977	-15.193	11.016	-92.16	
Standard deviation (SD)	12.459	7.243	8.346	14.762	9.414	
Sample size (N)	5	5	5	5	5	
Std. error of mean(SEM)	5.572	3.239	3.732	6.602	4.210	
Lower 95% conf. limit	-28.486	-12.969	-25.554	-7.311	-103.85	
Upper 95% conf. limit	2.448	5.015	-4.832	29.343	-80.473	

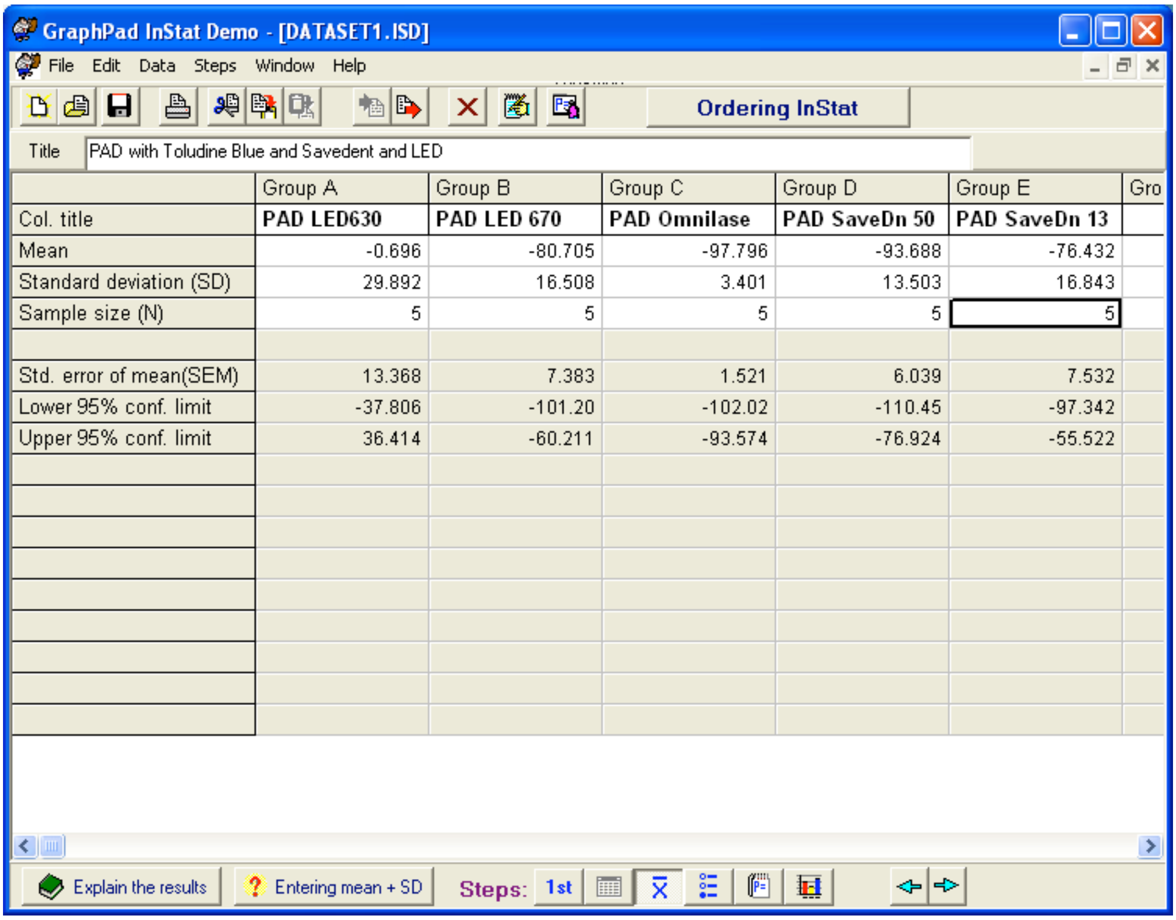


The P value is < 0.0001, considered extremely significant.
Variation among column means is significantly greater than expected by chance.

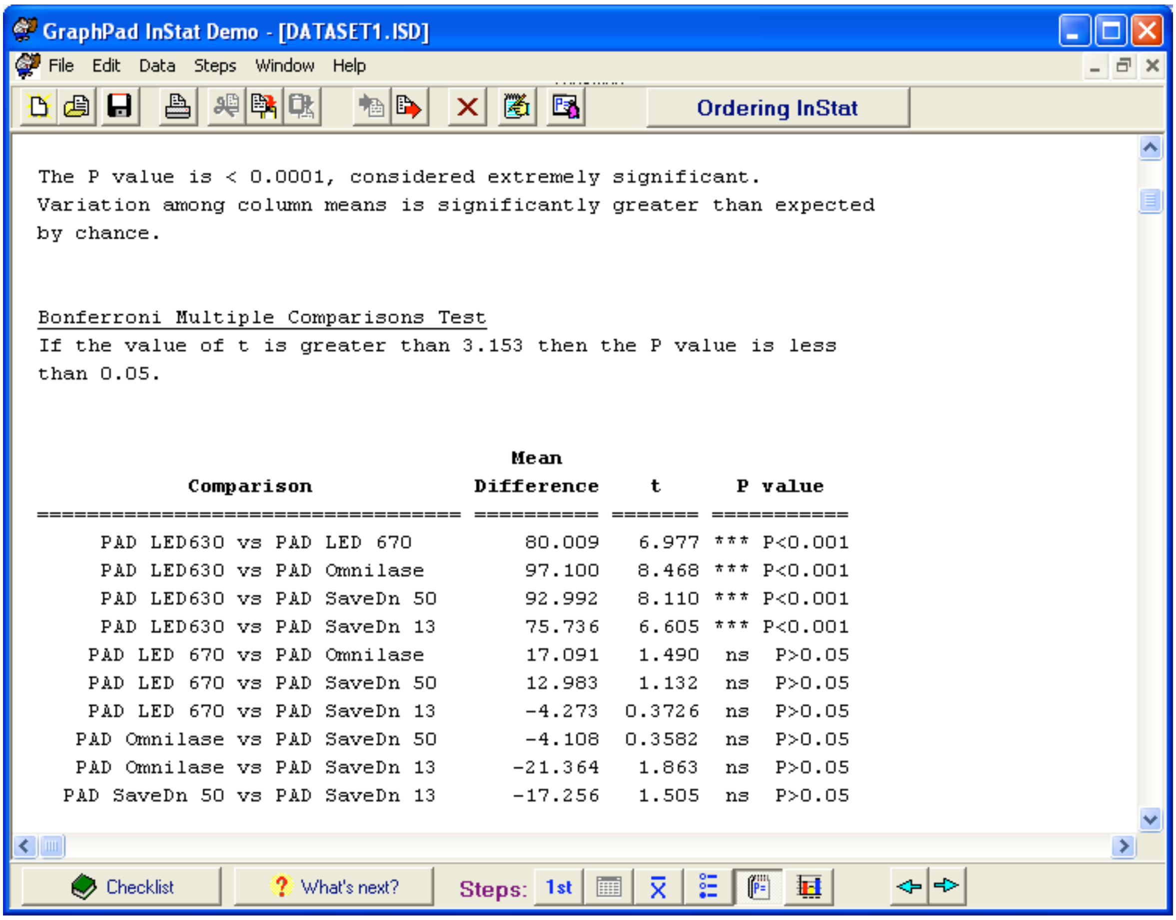
Bonferroni Multiple Comparisons Test

If the value of t is greater than 3.153 then the P value is less than 0.05.

Comparison	Mean Difference	t		P value
TolBlue control vs LED630	-9.042	1.323	ns	P>0.05
TolBlue control vs Savedent only	2.174	0.3181	ns	P>0.05
TolBlue control vs PAD 630	-24.035	3.517	*	P<0.05
TolBlue control vs PAD Savdent 50	79.141	11.580	***	P<0.001
LED630 vs Savedent only	11.216	1.641	ns	P>0.05
LED630 vs PAD 630	-14.993	2.194	ns	P>0.05
LED630 vs PAD Savdent 50	88.183	12.903	***	P<0.001
Savedent only vs PAD 630	-26.209	3.835	*	P<0.05
Savedent only vs PAD Savdent 50	76.967	11.262	***	P<0.001
PAD 630 vs PAD Savdent 50	103.18	15.096	***	P<0.001



	Group A	Group B	Group C	Group D	Group E	Gro
Col. title	PAD LED630	PAD LED 670	PAD Omnilase	PAD SaveDn 50	PAD SaveDn 13	
Mean	-0.696	-80.705	-97.796	-93.688	-76.432	
Standard deviation (SD)	29.892	16.508	3.401	13.503	16.843	
Sample size (N)	5	5	5	5	5	
Std. error of mean(SEM)	13.368	7.383	1.521	6.039	7.532	
Lower 95% conf. limit	-37.806	-101.20	-102.02	-110.45	-97.342	
Upper 95% conf. limit	36.414	-60.211	-93.574	-76.924	-55.522	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The P value is < 0.0001, considered extremely significant.
Variation among column means is significantly greater than expected by chance.
Bonferroni Multiple Comparisons Test
If the value of t is greater than 3.153 then the P value is less than 0.05.
Comparison | Mean Difference | t | P value
PAD LED630 vs PAD LED 670 | 80.009 | 6.977 | *** P<0.001
PAD LED630 vs PAD Omnilase | 97.100 | 8.468 | *** P<0.001
PAD LED630 vs PAD SaveDn 50 | 92.992 | 8.110 | *** P<0.001
PAD LED630 vs PAD SaveDn 13 | 75.736 | 6.605 | *** P<0.001
PAD LED 670 vs PAD Omnilase | 17.091 | 1.490 | ns P>0.05
PAD LED 670 vs PAD SaveDn 50 | 12.983 | 1.132 | ns P>0.05
PAD LED 670 vs PAD SaveDn 13 | -4.273 | 0.3726 | ns P>0.05
PAD Omnilase vs PAD SaveDn 50 | -4.108 | 0.3582 | ns P>0.05
PAD Omnilase vs PAD SaveDn 13 | -21.364 | 1.863 | ns P>0.05
PAD SaveDn 50 vs PAD SaveDn 13 | -17.256 | 1.505 | ns P>0.05
Checklist
What's next?
Steps: 1st

Appendix 10

Temperature changes during photoactivated disinfection

			LED 630nm	LED 670nm	Savedent 635nm	Omnilase 670nm
Sample 1	Zone1	Min	-0.541	-0.789	-0.021	-0.125
		Max	0	0	0.811	0.042
		Range	0.541(-)	0.789 (-)	0.832	0.167
	Zone 2	Min	-1.226	-0.187	0	-0.187
		Max	0	0.021	0.935	0.062
		Range	1.226 (-)	0.208	0.935	0.249
Sample 2	Zone1	Min	-0.665	-1.538	-0.042	-1.018
		Max	0	0	0.499	0
		Range	0.665 (-)	1.538 (-)	0.541	1.018 (-)
	Zone 2	Min	-0.353	-0.416	-0.021	-0.207
		Max	0.042	0	0.79	0
		Range	0.395	0.416 (-)	0.811	0.207 (-)
Sample 3	Zone1	Min	-0.935	-1.101	0	-0.749
		Max	0	0	2.743	0
		Range	0.935 (-)	1.101 (-)	2.743	0.749 (-)
	Zone 2	Min	-0.166	-0.52	0	-0.041
		Max	0.042	0.02	1.809	0.104
		Range	0.208	0.54	1.809	0.145
Sample 4	Zone1	Min	-1.912	-0.873	-0.041	-0.354
		Max	0	0	1.268	0
		Range	1.912 (-)	0.873 (-)	1.309	0.354 (-)
	Zone 2	Min	-0.229	-0.437	-0.042	-0.311
		Max	0	0	0.624	0.063
		Range	0.229 (-)	0.437 (-)	0.666	0.374
Sample 5	Zone1	Min	-1.06	-1.31	-0.063	-0.645
		Max	0	0	0.997	0
		Range	1.06 (-)	1.31 (-)	1.06	0.645 (-)
	Zone 2	Min	-0.52	-0.395	0	-0.083
		Max	0	0.062	1.143	0.021
		Range	0.52 (-)	0.457	1.143	0.104

Negative values indicate a decrease in temperature relative to the temperature at time 0.
Positive values indicate an increase in temperature relative to the temperature at time 0.
(-) signifies an overall decrease in temperature during the test period.

Appendix 11

Raw data for *Enterococcus faecalis*.

Experiment 1		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Milton											
1:1000000		N/A	N/A	N/A	N/A	N/A					
1:100000		N/A	N/A	N/A	N/A	N/A					
1:10000		0	0	0	0	0					
1:1000		0	0	0	0	0					
1:100		0	0	0	0	0					
Negative control											
1:1000000		5	6	2	3	2	3	3	2	2	2
1:100000		40	24	43	22	44		40	41	30	44
1:10000			421	403	342	404	306	300	307	388	307
1:1000		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1:100		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
MB dye control											
1:1000000		2	3	6	6	6					
1:100000		8	26		32	33					
1:10000		195	94	298	327	353					
1:1000		N/A	N/A	N/A	N/A	N/A					
1:100		N/A	N/A	N/A	N/A	N/A					
Omni control											
1:1000000		1	39	2	2	2					
1:100000		45	47	63	32	51					
1:10000		366	352	423	354	369					
1:1000		N/A	N/A	N/A	N/A	N/A					
1:100		N/A	N/A	N/A	N/A	N/A					
PAD Omni											
1:1000000		0	N/A	0	0	2					
1:100000		1	2	0	1	2					
1:10000		5	33	11	0	3					
1:1000		43	248	46	17	9					
1:100		261	N/A	468	191	N/A					
LED670 control											
1:1000000		5	1	7	2	4					
1:100000		31	31	36	30	38					
1:10000		259	337	355	290	303					
1:1000		N/A	N/A	N/A	N/A	N/A					
1:100		N/A	N/A	N/A	N/A	N/A					
PAD LED670											
1:1000000		1	0	1	0	1					
1:100000		13	0	5	1	6					
1:10000		124	17	38	10	94					
1:1000		N/A	151	272	150	748					
1:100		N/A	N/A	N/A	N/A	N/A					

Experiment 2		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8
Negative control									
1:1000000		5	0	1	10	1	1	3	0
1:100000		17	10	16	19	17	16	23	23
1:10000		168	192	142	166	135	166	193	183
1:1000		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1:100		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
TBO dye control									
1:1000000		4	0	2	1	1			
1:100000		10	13	21	19	12			
1:10000		115	157	173	158	157			
1:1000		N/A	N/A	N/A	N/A	N/A			
1:100		N/A	N/A	N/A	N/A	N/A			
SD50 control									
1:1000000		1	2	3	1	1			
1:100000		19	8	17	15	18			
1:10000		138	138	161	167	137			
1:1000		N/A	N/A	N/A	N/A	N/A			
1:100		N/A	N/A	N/A	N/A	N/A			
PAD SD50									
1:1000000		0	0	1	0	1			
1:100000		0	3	5	0	1			
1:10000		8	20	56	2	0			
1:1000		86	186	400	9	4			
1:100		N/A	N/A	N/A	N/A	N/A			
LED630 control									
1:1000000		0	3	2	1	1			
1:100000		18	23	15	11	25			
1:10000		140	171	134	160	178			
1:1000		N/A	N/A	N/A	N/A	N/A			
1:100		N/A	N/A	N/A	N/A	N/A			
PAD LED630									
1:1000000		2	4	1	2	1			
1:100000		19	19	18	6	23			
1:10000		154	201	225	154	200			
1:1000		N/A	N/A	N/A	N/A	N/A			
1:100		N/A	N/A	N/A	N/A	N/A			

Experiment 3		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Negative control							
1:1000000		N/A	N/A	N/A	N/A	N/A	
1:100000		27	34	21	15	19	
1:10000		168	192	142	166	135	
1:1000		N/A	N/A	N/A	N/A	N/A	
1:100		N/A	N/A	N/A	N/A	N/A	
PAD LED670							
1:1000000		N/A	N/A	N/A	N/A	N/A	N/A
1:100000		3	10	14	4	0	2
1:10000		40	69	158	103	10	10
1:1000		318	600	N/A	N/A	120	149
1:100		N/A	N/A	N/A	N/A	N/A	N/A
PAD LED630							
1:1000000		N/A	N/A	N/A	N/A	N/A	
1:100000		37	14	43	46	23	
1:10000		326	186	274	189	166	
1:1000		N/A	N/A	N/A	N/A	N/A	
1:100		N/A	N/A	N/A	N/A	N/A	
PAD Omni							
1:1000000		N/A	N/A	N/A	N/A	N/A	
1:100000		0	0	0	1	1	
1:10000		0	5	0	0	19	
1:1000		6	56	9	2	185	
1:100		68	381	25	29	N/A	
PAD SD50							
1:1000000		N/A	N/A	N/A	N/A	N/A	
1:100000		0	0	0	17	0	
1:10000		7	0	0	159	2	
1:1000		19	0	0	700	17	
1:100		75	5	2	N/A	286	
PADSD13							
1:1000000		N/A	N/A	N/A	N/A	N/A	
1:100000		15	2	10	0	26	
1:10000		47	19	70	26	114	
1:1000		380	164	806	324	N/A	
1:100		N/A	N/A	N/A	N/A	N/A	

Appendix 12

Raw temperature data: PAD 630

PAD LED630						
Sample 1						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	20.573	0	0	21.695	0
	1	20.51	-0.063	1	21.674	-0.021
	2	20.51	-0.063	2	21.633	-0.062
	3	20.531	-0.042	3	21.612	-0.083
	4	20.51	-0.063	4	21.591	-0.104
	5	20.469	-0.104	5	21.571	-0.124
	6	20.49	-0.083	6	21.55	-0.145
	7	20.49	-0.083	7	21.529	-0.166
	8	20.49	-0.083	8	21.487	-0.208
	9	20.49	-0.083	9	21.467	-0.228
	10	20.49	-0.083	10	21.446	-0.249
	11	20.469	-0.104	11	21.425	-0.27
	12	20.427	-0.146	12	21.404	-0.291
	13	20.469	-0.104	13	21.383	-0.312
	14	20.448	-0.125	14	21.3	-0.395
	15	20.448	-0.125	15	21.342	-0.353
	16	20.407	-0.166	16	21.321	-0.374
	17	20.427	-0.146	17	21.3	-0.395
	18	20.427	-0.146	18	21.321	-0.374
	19	20.407	-0.166	19	21.259	-0.436
	20	20.407	-0.166	20	21.196	-0.499
	21	20.386	-0.187	21	21.238	-0.457
	22	20.386	-0.187	22	21.217	-0.478
	23	20.365	-0.208	23	21.196	-0.499
	24	20.365	-0.208	24	21.155	-0.54
	25	20.344	-0.229	25	21.176	-0.519
	26	20.344	-0.229	26	21.155	-0.54
	27	20.323	-0.25	27	21.155	-0.54
	28	20.323	-0.25	28	21.092	-0.603
	29	20.323	-0.25	29	21.113	-0.582
	30	20.282	-0.291	30	21.072	-0.623
	31	20.303	-0.27	31	21.072	-0.623
	32	20.282	-0.291	32	21.072	-0.623
	33	20.282	-0.291	33	21.072	-0.623
	34	20.282	-0.291	34	21.051	-0.644
	35	20.219	-0.354	35	21.03	-0.665
	36	20.261	-0.312	36	21.03	-0.665
	37	20.199	-0.374	37	21.009	-0.686
	38	20.219	-0.354	38	21.009	-0.686
	39	20.24	-0.333	39	20.989	-0.706
	40	20.24	-0.333	40	20.968	-0.727

	41	20.24	-0.333	41	20.989	-0.706
	42	20.24	-0.333	42	20.947	-0.748
	43	20.219	-0.354	43	20.905	-0.79
	44	20.24	-0.333	44	20.926	-0.769
	45	20.178	-0.395	45	20.885	-0.81
	46	20.199	-0.374	46	20.947	-0.748
	47	20.178	-0.395	47	20.864	-0.831
	48	20.199	-0.374	48	20.905	-0.79
	49	20.157	-0.416	49	20.843	-0.852
	50	20.199	-0.374	50	20.885	-0.81
	51	20.157	-0.416	51	20.864	-0.831
	52	20.178	-0.395	52	20.864	-0.831
	53	20.136	-0.437	53	20.864	-0.831
	54	20.178	-0.395	54	20.843	-0.852
	55	20.136	-0.437	55	20.843	-0.852
	56	20.136	-0.437	56	20.843	-0.852
	57	20.157	-0.416	57	20.822	-0.873
	58	20.157	-0.416	58	20.822	-0.873
	59	20.157	-0.416	59	20.801	-0.894
	60	20.157	-0.416	60	20.801	-0.894
	61	20.157	-0.416	61	20.781	-0.914
	62	20.157	-0.416	62	20.801	-0.894
	63	20.136	-0.437	63	20.718	-0.977
	64	20.095	-0.478	64	20.781	-0.914
	65	20.136	-0.437	65	20.718	-0.977
	66	20.136	-0.437	66	20.76	-0.935
	67	20.136	-0.437	67	20.76	-0.935
	68	20.136	-0.437	68	20.76	-0.935
	69	20.116	-0.457	69	20.739	-0.956
	70	20.116	-0.457	70	20.739	-0.956
	71	20.116	-0.457	71	20.718	-0.977
	72	20.116	-0.457	72	20.718	-0.977
	73	20.116	-0.457	73	20.718	-0.977
	74	20.116	-0.457	74	20.718	-0.977
	75	20.116	-0.457	75	20.698	-0.997
	76	20.074	-0.499	76	20.698	-0.997
	77	20.095	-0.478	77	20.698	-0.997
	78	20.116	-0.457	78	20.677	-1.018
	79	20.074	-0.499	79	20.677	-1.018
	80	20.095	-0.478	80	20.677	-1.018
	81	20.053	-0.52	81	20.656	-1.039
	82	20.095	-0.478	82	20.656	-1.039
	83	20.074	-0.499	83	20.656	-1.039
	84	20.053	-0.52	84	20.635	-1.06
	85	20.095	-0.478	85	20.635	-1.06
	86	20.074	-0.499	86	20.635	-1.06

	87	20.074	-0.499	87	20.635	-1.06
	88	20.074	-0.499	88	20.635	-1.06
	89	20.095	-0.478	89	20.614	-1.081
	90	20.095	-0.478	90	20.614	-1.081
	91	20.116	-0.457	91	20.614	-1.081
	92	20.095	-0.478	92	20.614	-1.081
	93	20.095	-0.478	93	20.614	-1.081
	94	20.095	-0.478	94	20.635	-1.06
	95	20.095	-0.478	95	20.594	-1.101
	96	20.095	-0.478	96	20.594	-1.101
	97	20.095	-0.478	97	20.594	-1.101
	98	20.095	-0.478	98	20.594	-1.101
	99	20.095	-0.478	99	20.594	-1.101
	100	20.095	-0.478	100	20.573	-1.122
	101	20.074	-0.499	101	20.573	-1.122
	102	20.074	-0.499	102	20.573	-1.122
	103	20.074	-0.499	103	20.573	-1.122
	104	20.074	-0.499	104	20.552	-1.143
	105	20.074	-0.499	105	20.552	-1.143

	106	20.053	-0.52	106	20.552	-1.143
	107	20.032	-0.541	107	20.552	-1.143
	108	20.053	-0.52	108	20.552	-1.143
	109	20.053	-0.52	109	20.49	-1.205
	110	20.053	-0.52	110	20.552	-1.143
	111	20.053	-0.52	111	20.531	-1.164
	112	20.053	-0.52	112	20.531	-1.164
	113	20.053	-0.52	113	20.469	-1.226
	114	20.053	-0.52	114	20.49	-1.205
	115	20.053	-0.52	115	20.49	-1.205
	116	20.053	-0.52	116	20.49	-1.205
	117	20.053	-0.52	117	20.531	-1.164
	118	20.053	-0.52	118	20.469	-1.226
	119	20.053	-0.52	119	20.51	-1.185
	120	20.032	-0.541	120	20.469	-1.226
Min			-0.541			-1.226
Max			0			0
Range			0.541			1.226

PAD LED630

Sample 2

Zone 1			Zone 2		
Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
0	20.968	0	0	21.009	0
1	20.947	-0.021	1	21.051	0.042
2	20.947	-0.021	2	21.051	0.042
3	20.926	-0.042	3	21.051	0.042
4	20.926	-0.042	4	21.03	0.021
5	20.885	-0.083	5	21.03	0.021
6	20.905	-0.063	6	21.03	0.021
7	20.905	-0.063	7	20.968	-0.041
8	20.905	-0.063	8	21.03	0.021
9	20.905	-0.063	9	21.03	0.021
10	20.885	-0.083	10	20.989	-0.02
11	20.885	-0.083	11	21.009	0
12	20.822	-0.146	12	21.009	0
13	20.864	-0.104	13	21.009	0
14	20.864	-0.104	14	20.947	-0.062
15	20.843	-0.125	15	20.989	-0.02
16	20.822	-0.146	16	20.989	-0.02
17	20.843	-0.125	17	20.989	-0.02
18	20.822	-0.146	18	20.989	-0.02
19	20.822	-0.146	19	20.968	-0.041
20	20.822	-0.146	20	20.968	-0.041
21	20.781	-0.187	21	20.968	-0.041
22	20.801	-0.167	22	20.968	-0.041
23	20.801	-0.167	23	20.968	-0.041
24	20.801	-0.167	24	20.947	-0.062
25	20.781	-0.187	25	20.947	-0.062
26	20.781	-0.187	26	20.947	-0.062
27	20.781	-0.187	27	20.885	-0.124
28	20.76	-0.208	28	20.947	-0.062
29	20.76	-0.208	29	20.885	-0.124
30	20.739	-0.229	30	20.926	-0.083
31	20.739	-0.229	31	20.926	-0.083
32	20.739	-0.229	32	20.926	-0.083
33	20.718	-0.25	33	20.905	-0.104
34	20.718	-0.25	34	20.926	-0.083
35	20.718	-0.25	35	20.905	-0.104
36	20.677	-0.291	36	20.843	-0.166
37	20.698	-0.27	37	20.843	-0.166
38	20.698	-0.27	38	20.905	-0.104
39	20.698	-0.27	39	20.843	-0.166
40	20.677	-0.291	40	20.864	-0.145
41	20.677	-0.291	41	20.885	-0.124
42	20.656	-0.312	42	20.885	-0.124
43	20.656	-0.312	43	20.885	-0.124
44	20.656	-0.312	44	20.885	-0.124
45	20.656	-0.312	45	20.864	-0.145
46	20.635	-0.333	46	20.864	-0.145
47	20.635	-0.333	47	20.864	-0.145
48	20.635	-0.333	48	20.801	-0.208
49	20.635	-0.333	49	20.864	-0.145
50	20.594	-0.374	50	20.864	-0.145
51	20.614	-0.354	51	20.822	-0.187
52	20.614	-0.354	52	20.843	-0.166
53	20.614	-0.354	53	20.801	-0.208
54	20.614	-0.354	54	20.843	-0.166
55	20.614	-0.354	55	20.843	-0.166
56	20.594	-0.374	56	20.843	-0.166
57	20.594	-0.374	57	20.801	-0.208
58	20.594	-0.374	58	20.781	-0.228
59	20.594	-0.374	59	20.843	-0.166
60	20.552	-0.416	60	20.801	-0.208
61	20.594	-0.374	61	20.822	-0.187
62	20.573	-0.395	62	20.781	-0.228
63	20.573	-0.395	63	20.822	-0.187
64	20.573	-0.395	64	20.822	-0.187
65	20.573	-0.395	65	20.822	-0.187
66	20.552	-0.416	66	20.801	-0.208
67	20.51	-0.458	67	20.801	-0.208
68	20.531	-0.437	68	20.801	-0.208
69	20.531	-0.437	69	20.801	-0.208
70	20.531	-0.437	70	20.801	-0.208
71	20.531	-0.437	71	20.801	-0.208
72	20.49	-0.478	72	20.801	-0.208
73	20.448	-0.52	73	20.801	-0.208
74	20.51	-0.458	74	20.739	-0.27
75	20.51	-0.458	75	20.781	-0.228
76	20.49	-0.478	76	20.781	-0.228
77	20.49	-0.478	77	20.781	-0.228
78	20.49	-0.478	78	20.781	-0.228
79	20.49	-0.478	79	20.781	-0.228
80	20.49	-0.478	80	20.781	-0.228
81	20.469	-0.499	81	20.822	-0.187
82	20.469	-0.499	82	20.76	-0.249
83	20.469	-0.499	83	20.76	-0.249
84	20.469	-0.499	84	20.76	-0.249
85	20.469	-0.499	85	20.76	-0.249
86	20.448	-0.52	86	20.76	-0.249
87	20.448	-0.52	87	20.76	-0.249
88	20.448	-0.52	88	20.76	-0.249
89	20.448	-0.52	89	20.76	-0.249
90	20.407	-0.561	90	20.76	-0.249
91	20.427	-0.541	91	20.739	-0.27
92	20.407	-0.561	92	20.739	-0.27
93	20.427	-0.541	93	20.739	-0.27
94	20.427	-0.541	94	20.739	-0.27

	95	20.407	-0.561	95	20.739	-0.27
	96	20.407	-0.561	96	20.677	-0.332
	97	20.407	-0.561	97	20.718	-0.291
	98	20.407	-0.561	98	20.718	-0.291
	99	20.407	-0.561	99	20.718	-0.291
	100	20.365	-0.603	100	20.698	-0.311
	101	20.407	-0.561	101	20.718	-0.291
	102	20.407	-0.561	102	20.677	-0.332
	103	20.386	-0.582	103	20.718	-0.291
	104	20.386	-0.582	104	20.718	-0.291
	105	20.386	-0.582	105	20.718	-0.291
	106	20.386	-0.582	106	20.718	-0.291
	107	20.386	-0.582	107	20.656	-0.353
	108	20.365	-0.603	108	20.718	-0.291
	109	20.365	-0.603	109	20.718	-0.291

	110	20.365	-0.603	110	20.698	-0.311
	111	20.365	-0.603	111	20.698	-0.311
	112	20.365	-0.603	112	20.698	-0.311
	113	20.303	-0.665	113	20.698	-0.311
	114	20.344	-0.624	114	20.698	-0.311
	115	20.344	-0.624	115	20.698	-0.311
	116	20.344	-0.624	116	20.698	-0.311
	117	20.344	-0.624	117	20.698	-0.311
	118	20.344	-0.624	118	20.698	-0.311
	119	20.344	-0.624	119	20.698	-0.311
	120	20.323	-0.645	120	20.698	-0.311
Min			-0.665			-0.353
Max			0			0.042
Range			0.665			0.395

PAD LED630

Sample 3

Zone 1			Zone 2		
Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
0	21.82	0	0	21.404	0
1	21.799	-0.021	1	21.446	0.042
2	21.778	-0.042	2	21.446	0.042
3	21.778	-0.042	3	21.446	0.042
4	21.758	-0.062	4	21.446	0.042
5	21.758	-0.062	5	21.446	0.042
6	21.737	-0.083	6	21.425	0.021
7	21.758	-0.062	7	21.425	0.021
8	21.695	-0.125	8	21.363	-0.041
9	21.695	-0.125	9	21.383	-0.021
10	21.674	-0.146	10	21.363	-0.041
11	21.674	-0.146	11	21.425	0.021
12	21.654	-0.166	12	21.425	0.021
13	21.654	-0.166	13	21.425	0.021
14	21.633	-0.187	14	21.404	0
15	21.633	-0.187	15	21.404	0
16	21.591	-0.229	16	21.404	0
17	21.612	-0.208	17	21.404	0
18	21.612	-0.208	18	21.404	0
19	21.591	-0.229	19	21.404	0
20	21.571	-0.249	20	21.404	0
21	21.571	-0.249	21	21.383	-0.021
22	21.571	-0.249	22	21.321	-0.083
23	21.55	-0.27	23	21.383	-0.021
24	21.529	-0.291	24	21.321	-0.083
25	21.529	-0.291	25	21.383	-0.021
26	21.529	-0.291	26	21.383	-0.021
27	21.508	-0.312	27	21.383	-0.021
28	21.467	-0.353	28	21.383	-0.021
29	21.508	-0.312	29	21.383	-0.021
30	21.487	-0.333	30	21.342	-0.062
31	21.425	-0.395	31	21.363	-0.041
32	21.487	-0.333	32	21.321	-0.083
33	21.467	-0.353	33	21.363	-0.041
34	21.467	-0.353	34	21.363	-0.041
35	21.446	-0.374	35	21.363	-0.041
36	21.446	-0.374	36	21.363	-0.041
37	21.425	-0.395	37	21.363	-0.041
38	21.363	-0.457	38	21.363	-0.041
39	21.425	-0.395	39	21.363	-0.041
40	21.404	-0.416	40	21.363	-0.041
41	21.404	-0.416	41	21.342	-0.062
42	21.383	-0.437	42	21.342	-0.062
43	21.321	-0.499	43	21.342	-0.062
44	21.342	-0.478	44	21.342	-0.062
45	21.363	-0.457	45	21.342	-0.062
46	21.363	-0.457	46	21.342	-0.062
47	21.342	-0.478	47	21.342	-0.062
48	21.363	-0.457	48	21.28	-0.124
49	21.321	-0.499	49	21.342	-0.062
50	21.321	-0.499	50	21.342	-0.062
51	21.3	-0.52	51	21.342	-0.062
52	21.3	-0.52	52	21.342	-0.062
53	21.3	-0.52	53	21.342	-0.062
54	21.28	-0.54	54	21.342	-0.062
55	21.217	-0.603	55	21.342	-0.062
56	21.259	-0.561	56	21.3	-0.104
57	21.259	-0.561	57	21.28	-0.124
58	21.259	-0.561	58	21.342	-0.062
59	21.217	-0.603	59	21.321	-0.083
60	21.238	-0.582	60	21.321	-0.083
61	21.238	-0.582	61	21.321	-0.083
62	21.238	-0.582	62	21.321	-0.083
63	21.217	-0.603	63	21.321	-0.083
64	21.176	-0.644	64	21.321	-0.083
65	21.155	-0.665	65	21.321	-0.083
66	21.155	-0.665	66	21.3	-0.104
67	21.196	-0.624	67	21.321	-0.083
68	21.176	-0.644	68	21.321	-0.083
69	21.176	-0.644	69	21.321	-0.083
70	21.176	-0.644	70	21.28	-0.124
71	21.176	-0.644	71	21.342	-0.062
72	21.155	-0.665	72	21.321	-0.083
73	21.155	-0.665	73	21.321	-0.083
74	21.176	-0.644	74	21.321	-0.083
75	21.134	-0.686	75	21.321	-0.083
76	21.134	-0.686	76	21.321	-0.083
77	21.113	-0.707	77	21.321	-0.083
78	21.113	-0.707	78	21.321	-0.083
79	21.113	-0.707	79	21.28	-0.124
80	21.113	-0.707	80	21.321	-0.083
81	21.113	-0.707	81	21.28	-0.124
82	21.092	-0.728	82	21.28	-0.124
83	21.113	-0.707	83	21.3	-0.104
84	21.072	-0.748	84	21.321	-0.083
85	21.072	-0.748	85	21.3	-0.104
86	21.072	-0.748	86	21.3	-0.104
87	21.072	-0.748	87	21.3	-0.104
88	21.072	-0.748	88	21.3	-0.104
89	21.051	-0.769	89	21.3	-0.104
90	21.009	-0.811	90	21.3	-0.104
91	21.009	-0.811	91	21.3	-0.104
92	21.03	-0.79	92	21.3	-0.104
93	21.051	-0.769	93	21.3	-0.104
94	21.03	-0.79	94	21.3	-0.104

	95	21.03	-0.79	95	21.3	-0.104
	96	21.03	-0.79	96	21.3	-0.104
	97	21.009	-0.811	97	21.3	-0.104
	98	21.009	-0.811	98	21.3	-0.104
	99	21.009	-0.811	99	21.238	-0.166
	100	21.009	-0.811	100	21.3	-0.104
	101	20.968	-0.852	101	21.321	-0.083
	102	20.989	-0.831	102	21.3	-0.104
	103	20.989	-0.831	103	21.3	-0.104
	104	20.947	-0.873	104	21.3	-0.104
	105	20.989	-0.831	105	21.259	-0.145
	106	20.926	-0.894	106	21.259	-0.145
	107	20.968	-0.852	107	21.3	-0.104
	108	20.947	-0.873	108	21.3	-0.104
	109	20.968	-0.852	109	21.3	-0.104

	110	20.968	-0.852	110	21.259	-0.145
	111	20.947	-0.873	111	21.28	-0.124
	112	20.947	-0.873	112	21.28	-0.124
	113	20.968	-0.852	113	21.3	-0.104
	114	20.947	-0.873	114	21.28	-0.124
	115	20.926	-0.894	115	21.28	-0.124
	116	20.905	-0.915	116	21.321	-0.083
	117	20.885	-0.935	117	21.321	-0.083
	118	20.885	-0.935	118	21.28	-0.124
	119	20.885	-0.935	119	21.3	-0.104
	120	20.905	-0.915	120	21.28	-0.124
Min			-0.935			-0.166
Max			0			0.042
Range			0.935			0.208

PAD LED630

Sample 4

	Zone 1			Zone 2	
Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
0	23.358	0	0	21.467	0
1	23.337	-0.021	1	21.467	0
2	23.296	-0.062	2	21.467	0
3	23.275	-0.083	3	21.467	0
4	23.233	-0.125	4	21.446	-0.021
5	23.213	-0.145	5	21.446	-0.021
6	23.192	-0.166	6	21.446	-0.021
7	23.171	-0.187	7	21.446	-0.021
8	23.088	-0.27	8	21.446	-0.021
9	23.109	-0.249	9	21.446	-0.021
10	23.088	-0.27	10	21.446	-0.021
11	23.067	-0.291	11	21.446	-0.021
12	23.046	-0.312	12	21.446	-0.021
13	23.005	-0.353	13	21.425	-0.042
14	23.005	-0.353	14	21.425	-0.042
15	22.963	-0.395	15	21.425	-0.042
16	22.942	-0.416	16	21.425	-0.042
17	22.922	-0.436	17	21.425	-0.042
18	22.901	-0.457	18	21.425	-0.042
19	22.88	-0.478	19	21.425	-0.042
20	22.859	-0.499	20	21.404	-0.063
21	22.838	-0.52	21	21.404	-0.063
22	22.818	-0.54	22	21.404	-0.063
23	22.755	-0.603	23	21.404	-0.063
24	22.776	-0.582	24	21.404	-0.063
25	22.693	-0.665	25	21.404	-0.063
26	22.734	-0.624	26	21.404	-0.063
27	22.693	-0.665	27	21.425	-0.042
28	22.672	-0.686	28	21.404	-0.063
29	22.651	-0.707	29	21.383	-0.084
30	22.631	-0.727	30	21.383	-0.084
31	22.61	-0.748	31	21.383	-0.084
32	22.589	-0.769	32	21.383	-0.084
33	22.568	-0.79	33	21.383	-0.084
34	22.568	-0.79	34	21.342	-0.125
35	22.485	-0.873	35	21.321	-0.146
36	22.485	-0.873	36	21.383	-0.084
37	22.485	-0.873	37	21.342	-0.125
38	22.485	-0.873	38	21.383	-0.084
39	22.464	-0.894	39	21.383	-0.084
40	22.443	-0.915	40	21.363	-0.104
41	22.423	-0.935	41	21.363	-0.104
42	22.381	-0.977	42	21.363	-0.104
43	22.36	-0.998	43	21.363	-0.104
44	22.34	-1.018	44	21.363	-0.104
45	22.277	-1.081	45	21.321	-0.146
46	22.319	-1.039	46	21.363	-0.104
47	22.298	-1.06	47	21.3	-0.167
48	22.236	-1.122	48	21.321	-0.146
49	22.256	-1.102	49	21.3	-0.167
50	22.256	-1.102	50	21.363	-0.104
51	22.236	-1.122	51	21.3	-0.167
52	22.215	-1.143	52	21.342	-0.125
53	22.194	-1.164	53	21.321	-0.146
54	22.194	-1.164	54	21.342	-0.125
55	22.173	-1.185	55	21.342	-0.125
56	22.152	-1.206	56	21.3	-0.167
57	22.152	-1.206	57	21.342	-0.125
58	22.132	-1.226	58	21.342	-0.125
59	22.111	-1.247	59	21.342	-0.125
60	22.09	-1.268	60	21.342	-0.125
61	22.09	-1.268	61	21.342	-0.125
62	22.069	-1.289	62	21.342	-0.125
63	22.049	-1.309	63	21.342	-0.125
64	22.028	-1.33	64	21.321	-0.146
65	21.986	-1.372	65	21.321	-0.146
66	21.945	-1.413	66	21.321	-0.146
67	21.986	-1.372	67	21.321	-0.146
68	21.965	-1.393	68	21.321	-0.146
69	21.965	-1.393	69	21.321	-0.146
70	21.924	-1.434	70	21.321	-0.146
71	21.924	-1.434	71	21.321	-0.146
72	21.924	-1.434	72	21.321	-0.146
73	21.862	-1.496	73	21.321	-0.146
74	21.882	-1.476	74	21.321	-0.146
75	21.882	-1.476	75	21.321	-0.146
76	21.862	-1.496	76	21.321	-0.146
77	21.841	-1.517	77	21.321	-0.146
78	21.841	-1.517	78	21.321	-0.146
79	21.82	-1.538	79	21.321	-0.146
80	21.82	-1.538	80	21.3	-0.167
81	21.758	-1.6	81	21.28	-0.187
82	21.737	-1.621	82	21.3	-0.167
83	21.778	-1.58	83	21.3	-0.167
84	21.716	-1.642	84	21.3	-0.167
85	21.758	-1.6	85	21.3	-0.167
86	21.758	-1.6	86	21.3	-0.167
87	21.695	-1.663	87	21.3	-0.167
88	21.737	-1.621	88	21.3	-0.167
89	21.674	-1.684	89	21.3	-0.167
90	21.674	-1.684	90	21.3	-0.167
91	21.695	-1.663	91	21.3	-0.167
92	21.654	-1.704	92	21.259	-0.208
93	21.633	-1.725	93	21.28	-0.187
94	21.633	-1.725	94	21.28	-0.187

	95	21.654	-1.704	95	21.28	-0.187
	96	21.612	-1.746	96	21.28	-0.187
	97	21.633	-1.725	97	21.28	-0.187
	98	21.633	-1.725	98	21.259	-0.208
	99	21.612	-1.746	99	21.238	-0.229
	100	21.571	-1.787	100	21.28	-0.187
	101	21.612	-1.746	101	21.28	-0.187
	102	21.591	-1.767	102	21.28	-0.187
	103	21.55	-1.808	103	21.259	-0.208
	104	21.571	-1.787	104	21.28	-0.187
	105	21.571	-1.787	105	21.28	-0.187
	106	21.571	-1.787	106	21.28	-0.187
	107	21.55	-1.808	107	21.28	-0.187
	108	21.55	-1.808	108	21.28	-0.187
	109	21.529	-1.829	109	21.28	-0.187

	110	21.529	-1.829	110	21.28	-0.187
	111	21.529	-1.829	111	21.259	-0.208
	112	21.508	-1.85	112	21.28	-0.187
	113	21.508	-1.85	113	21.28	-0.187
	114	21.508	-1.85	114	21.259	-0.208
	115	21.487	-1.871	115	21.28	-0.187
	116	21.487	-1.871	116	21.259	-0.208
	117	21.487	-1.871	117	21.259	-0.208
	118	21.467	-1.891	118	21.238	-0.229
	119	21.467	-1.891	119	21.28	-0.187
	120	21.446	-1.912	120	21.259	-0.208
Min			-1.912			-0.229
Max			0			0
Range			1.912			0.229

PAD LED630							
Sample 5							
	Zone 1			Zone 2			
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	21.508	0	0	21.425	0
	1	21.508	0	1	21.425	0
	2	21.487	-0.021	2	21.425	0
	3	21.487	-0.021	3	21.425	0
	4	21.467	-0.041	4	21.404	-0.021
	5	21.446	-0.062	5	21.383	-0.042
	6	21.404	-0.104	6	21.404	-0.021
	7	21.383	-0.125	7	21.404	-0.021
	8	21.425	-0.083	8	21.383	-0.042
	9	21.404	-0.104	9	21.383	-0.042
	10	21.404	-0.104	10	21.321	-0.104
	11	21.383	-0.125	11	21.383	-0.042
	12	21.363	-0.145	12	21.363	-0.062
	13	21.3	-0.208	13	21.363	-0.062
	14	21.321	-0.187	14	21.321	-0.104
	15	21.28	-0.228	15	21.363	-0.062
	16	21.3	-0.208	16	21.3	-0.125
	17	21.321	-0.187	17	21.342	-0.083
	18	21.28	-0.228	18	21.342	-0.083
	19	21.3	-0.208	19	21.321	-0.104
	20	21.3	-0.208	20	21.342	-0.083
	21	21.28	-0.228	21	21.28	-0.145
	22	21.28	-0.228	22	21.321	-0.104
	23	21.259	-0.249	23	21.3	-0.125
	24	21.259	-0.249	24	21.3	-0.125
	25	21.217	-0.291	25	21.238	-0.187
	26	21.196	-0.312	26	21.259	-0.166
	27	21.238	-0.27	27	21.28	-0.145
	28	21.217	-0.291	28	21.28	-0.145
	29	21.217	-0.291	29	21.28	-0.145
	30	21.217	-0.291	30	21.217	-0.208
	31	21.155	-0.353	31	21.259	-0.166
	32	21.134	-0.374	32	21.259	-0.166
	33	21.176	-0.332	33	21.259	-0.166
	34	21.155	-0.353	34	21.259	-0.166
	35	21.155	-0.353	35	21.238	-0.187
	36	21.134	-0.374	36	21.238	-0.187
	37	21.134	-0.374	37	21.238	-0.187
	38	21.134	-0.374	38	21.238	-0.187
	39	21.113	-0.395	39	21.217	-0.208
	40	21.113	-0.395	40	21.217	-0.208
	41	21.092	-0.416	41	21.217	-0.208
	42	21.092	-0.416	42	21.155	-0.27
	43	21.092	-0.416	43	21.196	-0.229
	44	21.072	-0.436	44	21.196	-0.229
	45	21.051	-0.457	45	21.196	-0.229
	46	21.051	-0.457	46	21.196	-0.229
	47	21.051	-0.457	47	21.176	-0.249
	48	21.03	-0.478	48	21.176	-0.249
	49	21.009	-0.499	49	21.176	-0.249
	50	21.009	-0.499	50	21.176	-0.249
	51	20.968	-0.54	51	21.134	-0.291
	52	20.989	-0.519	52	21.155	-0.27
	53	20.989	-0.519	53	21.155	-0.27
	54	20.989	-0.519	54	21.155	-0.27
	55	20.947	-0.561	55	21.155	-0.27
	56	20.968	-0.54	56	21.134	-0.291
	57	20.968	-0.54	57	21.092	-0.333
	58	20.947	-0.561	58	21.092	-0.333
	59	20.885	-0.623	59	21.134	-0.291
	60	20.926	-0.582	60	21.113	-0.312
	61	20.926	-0.582	61	21.113	-0.312
	62	20.926	-0.582	62	21.092	-0.333
	63	20.905	-0.603	63	21.113	-0.312
	64	20.905	-0.603	64	21.113	-0.312
	65	20.885	-0.623	65	21.113	-0.312
	66	20.885	-0.623	66	21.051	-0.374
	67	20.843	-0.665	67	21.072	-0.353
	68	20.822	-0.686	68	21.092	-0.333
	69	20.864	-0.644	69	21.051	-0.374
	70	20.843	-0.665	70	21.092	-0.333
	71	20.843	-0.665	71	21.113	-0.312
	72	20.843	-0.665	72	21.072	-0.353
	73	20.822	-0.686	73	21.072	-0.353
	74	20.822	-0.686	74	21.072	-0.353
	75	20.801	-0.707	75	21.072	-0.353
	76	20.801	-0.707	76	21.051	-0.374
	77	20.781	-0.727	77	21.051	-0.374
	78	20.781	-0.727	78	21.03	-0.395
	79	20.76	-0.748	79	21.009	-0.416
	80	20.76	-0.748	80	21.051	-0.374
	81	20.739	-0.769	81	21.009	-0.416
	82	20.698	-0.81	82	20.989	-0.436
	83	20.698	-0.81	83	21.03	-0.395
	84	20.739	-0.769	84	21.03	-0.395
	85	20.718	-0.79	85	21.03	-0.395
	86	20.718	-0.79	86	20.989	-0.436
	87	20.718	-0.79	87	21.03	-0.395
	88	20.698	-0.81	88	20.989	-0.436
	89	20.635	-0.873	89	21.009	-0.416
	90	20.698	-0.81	90	21.009	-0.416
	91	20.718	-0.79	91	21.009	-0.416
	92	20.677	-0.831	92	20.947	-0.478
	93	20.677	-0.831	93	20.968	-0.457
	94	20.656	-0.852	94	21.009	-0.416

	95	20.656	-0.852	95	21.009	-0.416
	96	20.656	-0.852	96	20.989	-0.436
	97	20.614	-0.894	97	20.989	-0.436
	98	20.635	-0.873	98	20.989	-0.436
	99	20.635	-0.873	99	20.926	-0.499
	100	20.635	-0.873	100	20.989	-0.436
	101	20.614	-0.894	101	20.989	-0.436
	102	20.614	-0.894	102	20.968	-0.457
	103	20.614	-0.894	103	20.947	-0.478
	104	20.614	-0.894	104	20.968	-0.457
	105	20.594	-0.914	105	20.968	-0.457
	106	20.594	-0.914	106	20.968	-0.457
	107	20.594	-0.914	107	20.968	-0.457
	108	20.573	-0.935	108	20.968	-0.457
	109	20.573	-0.935	109	20.947	-0.478

	110	20.573	-0.935	110	20.968	-0.457
	111	20.552	-0.956	111	20.947	-0.478
	112	20.552	-0.956	112	20.947	-0.478
	113	20.552	-0.956	113	20.905	-0.52
	114	20.552	-0.956	114	20.905	-0.52
	115	20.531	-0.977	115	20.947	-0.478
	116	20.49	-1.018	116	20.968	-0.457
	117	20.531	-0.977	117	20.905	-0.52
	118	20.469	-1.039	118	20.926	-0.499
	119	20.49	-1.018	119	20.905	-0.52
	120	20.448	-1.06	120	20.926	-0.499
Min			-1.06			-0.52
Max			0			0
Range			1.06			0.52

Raw temperature data: PAD 670

PAD LED670						
Sample 1						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	20.905	0	0	20.427	0
	1	20.885	-0.02	1	20.448	0.021
	2	20.885	-0.02	2	20.407	-0.02
	3	20.864	-0.041	3	20.407	-0.02
	4	20.801	-0.104	4	20.407	-0.02
	5	20.843	-0.062	5	20.344	-0.083
	6	20.822	-0.083	6	20.407	-0.02
	7	20.822	-0.083	7	20.386	-0.041
	8	20.801	-0.104	8	20.386	-0.041
	9	20.801	-0.104	9	20.386	-0.041
	10	20.781	-0.124	10	20.386	-0.041
	11	20.781	-0.124	11	20.323	-0.104
	12	20.76	-0.145	12	20.386	-0.041
	13	20.739	-0.166	13	20.386	-0.041
	14	20.739	-0.166	14	20.386	-0.041
	15	20.718	-0.187	15	20.386	-0.041
	16	20.656	-0.249	16	20.386	-0.041
	17	20.698	-0.207	17	20.386	-0.041
	18	20.677	-0.228	18	20.386	-0.041
	19	20.677	-0.228	19	20.386	-0.041
	20	20.656	-0.249	20	20.386	-0.041
	21	20.656	-0.249	21	20.386	-0.041
	22	20.635	-0.27	22	20.386	-0.041
	23	20.573	-0.332	23	20.386	-0.041
	24	20.573	-0.332	24	20.386	-0.041
	25	20.552	-0.353	25	20.386	-0.041
	26	20.531	-0.374	26	20.386	-0.041
	27	20.594	-0.311	27	20.323	-0.104
	28	20.573	-0.332	28		-0.083
	29	20.573	-0.332	29	20.344 20.407	-0.02
	30	20.552	-0.353	30	20.365	-0.062
	31	20.552	-0.353	31	20.365	-0.062
	32	20.49	-0.415	32	20.386	-0.041
	33	20.531	-0.374	33	20.365	-0.062
	34	20.531	-0.374	34	20.323	-0.104
	35	20.531	-0.374	35	20.365	-0.062
	36	20.51	-0.395	36	20.303	-0.124
	37	20.51	-0.395	37	20.344	-0.083
	38	20.51	-0.395	38	20.365	-0.062
	39	20.49	-0.415	39	20.365	-0.062
	40	20.49	-0.415	40	20.365	-0.062
	41	20.49	-0.415	41	20.365	-0.062
	42	20.49	-0.415	42	20.365	-0.062
	43	20.469	-0.436	43	20.365	-0.062
	44	20.407	-0.498	44	20.365	-0.062
	45	20.427	-0.478	45	20.344	-0.083
	46	20.386	-0.519	46	20.344	-0.083
	47	20.448	-0.457	47	20.344	-0.083
	48	20.427	-0.478	48	20.344	-0.083
	49	20.427	-0.478	49	20.344	-0.083
	50	20.427	-0.478	50	20.282	-0.145
	51	20.407	-0.498	51	20.344	-0.083
	52	20.407	-0.498	52	20.344	-0.083
	53	20.386	-0.519	53	20.344	-0.083
	54	20.386	-0.519	54	20.365	-0.062
	55	20.365	-0.54	55	20.344	-0.083
	56	20.303	-0.602	56	20.344	-0.083
	57	20.365	-0.54	57	20.344	-0.083
	58	20.365	-0.54	58	20.323	-0.104
	59	20.344	-0.561	59	20.323	-0.104
	60	20.282	-0.623	60	20.323	-0.104
	61	20.303	-0.602	61	20.344	-0.083
	62	20.282	-0.623	62	20.344	-0.083
	63	20.344	-0.561	63	20.323	-0.104
	64	20.261	-0.644	64	20.344	-0.083
	65	20.323	-0.582	65	20.323	-0.104
	66	20.323	-0.582	66	20.323	-0.104
	67	20.323	-0.582	67	20.323	-0.104
	68	20.323	-0.582	68	20.323	-0.104
	69	20.303	-0.602	69	20.323	-0.104
	70	20.303	-0.602	70	20.323	-0.104
	71	20.282	-0.623	71	20.365	-0.062
	72	20.303	-0.602	72	20.323	-0.104
	73	20.303	-0.602	73	20.323	-0.104
	74	20.282	-0.623	74	20.323	-0.104
	75	20.282	-0.623	75	20.323	-0.104
	76	20.282	-0.623	76	20.261	-0.166
	77	20.282	-0.623	77	20.323	-0.104
	78	20.282	-0.623	78	20.323	-0.104
	79	20.261	-0.644	79	20.323	-0.104
	80	20.261	-0.644	80	20.323	-0.104
	81	20.261	-0.644	81	20.261	-0.166
	82	20.219	-0.686	82	20.323	-0.104
	83	20.199	-0.706	83	20.323	-0.104
	84	20.261	-0.644	84	20.323	-0.104
	85	20.199	-0.706	85	20.323	-0.104
	86	20.24	-0.665	86	20.323	-0.104
	87	20.178	-0.727	87	20.303	-0.124

	88	20.24	-0.665	88	20.303	-0.124
	89	20.24	-0.665	89	20.323	-0.104
	90	20.24	-0.665	90	20.303	-0.124
	91	20.219	-0.686	91	20.303	-0.124
	92	20.219	-0.686	92	20.303	-0.124
	93	20.219	-0.686	93	20.303	-0.124
	94	20.219	-0.686	94	20.303	-0.124
	95	20.219	-0.686	95	20.303	-0.124
	96	20.199	-0.706	96	20.303	-0.124
	97	20.199	-0.706	97	20.303	-0.124
	98	20.199	-0.706	98	20.303	-0.124
	99	20.199	-0.706	99	20.303	-0.124
	100	20.199	-0.706	100	20.303	-0.124
	101	20.199	-0.706	101	20.303	-0.124
	102	20.199	-0.706	102	20.303	-0.124
	103	20.199	-0.706	103	20.303	-0.124
	104	20.199	-0.706	104	20.24	-0.187
	105	20.136	-0.769	105	20.24	-0.187
	106	20.178	-0.727	106	20.261	-0.166

	107	20.136	-0.769	107	20.24	-0.187
	108	20.178	-0.727	108	20.261	-0.166
	109	20.116	-0.789	109	20.323	-0.104
	110	20.178	-0.727	110	20.282	-0.145
	111	20.157	-0.748	111	20.282	-0.145
	112	20.157	-0.748	112	20.282	-0.145
	113	20.157	-0.748	113	20.282	-0.145
	114	20.157	-0.748	114	20.24	-0.187
	115	20.157	-0.748	115	20.282	-0.145
	116	20.157	-0.748	116	20.282	-0.145
	117	20.157	-0.748	117	20.282	-0.145
	118	20.157	-0.748	118	20.282	-0.145
	119	20.157	-0.748	119	20.282	-0.145
	120	20.157	-0.748	120	20.282	-0.145
Min			-0.789			-0.187
Max			0			0.021
Range			0.789			0.208

PAD LED670					
Sample 2					
Zone 1			Zone 2		
Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
0	22.194	0	0	21.425	0
1	22.152	-0.042	1	21.425	0
2	22.132	-0.062	2	21.404	-0.021
3	22.111	-0.083	3	21.404	-0.021
4	22.09	-0.104	4	21.404	-0.021
5	22.069	-0.125	5	21.383	-0.042
6	22.049	-0.145	6	21.383	-0.042
7	22.028	-0.166	7	21.383	-0.042
8	22.007	-0.187	8	21.383	-0.042
9	21.986	-0.208	9	21.383	-0.042
10	21.965	-0.229	10	21.363	-0.062
11	21.965	-0.229	11	21.363	-0.062
12	21.903	-0.291	12	21.363	-0.062
13	21.924	-0.27	13	21.3	-0.125
14	21.862	-0.332	14	21.363	-0.062
15	21.82	-0.374	15	21.3	-0.125
16	21.862	-0.332	16	21.363	-0.062
17	21.841	-0.353	17	21.363	-0.062
18	21.82	-0.374	18	21.342	-0.083
19	21.799	-0.395	19	21.342	-0.083
20	21.778	-0.416	20	21.342	-0.083
21	21.758	-0.436	21	21.28	-0.145
22	21.737	-0.457	22	21.259	-0.166
23	21.695	-0.499	23	21.321	-0.104
24	21.654	-0.54	24	21.321	-0.104
25	21.674	-0.52	25	21.3	-0.125
26	21.633	-0.561	26	21.3	-0.125
27	21.654	-0.54	27	21.238	-0.187
28	21.654	-0.54	28	21.259	-0.166
29	21.633	-0.561	29	21.238	-0.187
30	21.612	-0.582	30	21.28	-0.145
31	21.591	-0.603	31	21.28	-0.145
32	21.571	-0.623	32	21.28	-0.145
33	21.55	-0.644	33	21.28	-0.145
34	21.55	-0.644	34	21.259	-0.166
35	21.529	-0.665	35	21.259	-0.166
36	21.529	-0.665	36	21.259	-0.166
37	21.508	-0.686	37	21.259	-0.166
38	21.487	-0.707	38	21.238	-0.187
39	21.467	-0.727	39	21.238	-0.187
40	21.467	-0.727	40	21.176	-0.249
41	21.446	-0.748	41	21.238	-0.187
42	21.425	-0.769	42	21.176	-0.249
43	21.404	-0.79	43	21.217	-0.208
44	21.404	-0.79	44	21.217	-0.208
45	21.383	-0.811	45	21.155	-0.27
46	21.383	-0.811	46	21.155	-0.27
47	21.363	-0.831	47	21.217	-0.208
48	21.342	-0.852	48	21.196	-0.229
49	21.28	-0.914	49	21.155	-0.27
50	21.3	-0.894	50	21.196	-0.229
51	21.3	-0.894	51	21.134	-0.291
52	21.3	-0.894	52	21.196	-0.229
53	21.28	-0.914	53	21.217	-0.208
54	21.28	-0.914	54	21.176	-0.249
55	21.259	-0.935	55	21.176	-0.249
56	21.196	-0.998	56	21.176	-0.249
57	21.238	-0.956	57	21.176	-0.249
58	21.176	-1.018	58	21.176	-0.249
59	21.217	-0.977	59	21.176	-0.249
60	21.196	-0.998	60	21.176	-0.249
61	21.217	-0.977	61	21.176	-0.249
62	21.176	-1.018	62	21.176	-0.249
63	21.113	-1.081	63	21.155	-0.27
64	21.155	-1.039	64	21.155	-0.27
65	21.134	-1.06	65	21.155	-0.27
66	21.134	-1.06	66	21.155	-0.27
67	21.113	-1.081	67	21.155	-0.27
68	21.113	-1.081	68	21.155	-0.27
69	21.092	-1.102	69	21.134	-0.291
70	21.092	-1.102	70	21.134	-0.291
71	21.03	-1.164	71	21.155	-0.27
72	21.072	-1.122	72	21.092	-0.333
73	21.051	-1.143	73	21.155	-0.27
74	21.051	-1.143	74	21.134	-0.291
75	21.03	-1.164	75	21.072	-0.353
76	21.03	-1.164	76	21.134	-0.291
77	21.009	-1.185	77	21.113	-0.312
78	21.009	-1.185	78	21.113	-0.312
79	20.989	-1.205	79	21.113	-0.312
80	20.989	-1.205	80	21.113	-0.312
81	20.968	-1.226	81	21.051	-0.374
82	20.968	-1.226	82	21.113	-0.312
83	20.968	-1.226	83	21.113	-0.312
84	20.947	-1.247	84	21.113	-0.312
85	20.947	-1.247	85	21.113	-0.312
86	20.926	-1.268	86	21.113	-0.312
87	20.926	-1.268	87	21.113	-0.312
88	20.926	-1.268	88	21.113	-0.312
89	20.905	-1.289	89	21.092	-0.333
90	20.905	-1.289	90	21.092	-0.333
91	20.885	-1.309	91	21.092	-0.333
92	20.822	-1.372	92	21.092	-0.333
93	20.885	-1.309	93	21.092	-0.333
94	20.864	-1.33	94	21.092	-0.333

	95	20.864	-1.33	95	21.092	-0.333
	96	20.843	-1.351	96	21.092	-0.333
	97	20.843	-1.351	97	21.092	-0.333
	98	20.843	-1.351	98	21.092	-0.333
	99	20.822	-1.372	99	21.092	-0.333
	100	20.822	-1.372	100	21.092	-0.333
	101	20.739	-1.455	101	21.092	-0.333
	102	20.801	-1.393	102	21.072	-0.353
	103	20.739	-1.455	103	21.092	-0.333
	104	20.781	-1.413	104	21.072	-0.353
	105	20.781	-1.413	105	21.072	-0.353
	106	20.76	-1.434	106	21.072	-0.353
	107	20.76	-1.434	107	21.072	-0.353
	108	20.739	-1.455	108	21.072	-0.353
	109	20.698	-1.496	109	21.072	-0.353

	110	20.76	-1.434	110	21.072	-0.353
	111	20.677	-1.517	111	21.072	-0.353
	112	20.656	-1.538	112	21.072	-0.353
	113	20.677	-1.517	113	21.072	-0.353
	114	20.656	-1.538	114	21.009	-0.416
	115	20.698	-1.496	115	21.051	-0.374
	116	20.698	-1.496	116	21.009	-0.416
	117	20.677	-1.517	117	21.051	-0.374
	118	20.677	-1.517	118	21.051	-0.374
	119	20.677	-1.517	119	21.051	-0.374
	120	20.656	-1.538	120	21.051	-0.374
Min			-1.538			-0.416
Max			0			0
Range			1.538			0.416

PAD LED670						
Sample 3						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	22.173	0	0	22.132	0
	1	22.152	-0.021	1	22.132	0
	2	22.132	-0.041	2	22.09	-0.042
	3	22.111	-0.062	3	22.152	0.02
	4	22.09	-0.083	4	22.152	0.02
	5	22.049	-0.124	5	22.132	0
	6	22.049	-0.124	6	22.132	0
	7	22.028	-0.145	7	22.069	-0.063
	8	22.007	-0.166	8	22.111	-0.021
	9	21.986	-0.187	9	22.049	-0.083
	10	21.903	-0.27	10	22.09	-0.042
	11	21.924	-0.249	11	22.111	-0.021
	12	21.882	-0.291	12	22.09	-0.042
	13	21.924	-0.249	13	22.09	-0.042
	14	21.862	-0.311	14	22.069	-0.063
	15	21.903	-0.27	15	22.049	-0.083
	16	21.903	-0.27	16	22.049	-0.083
	17	21.882	-0.291	17	22.049	-0.083
	18	21.862	-0.311	18	22.028	-0.104
	19	21.778	-0.395	19	22.028	-0.104
	20	21.82	-0.353	20	22.007	-0.125
	21	21.799	-0.374	21	21.945	-0.187
	22	21.778	-0.395	22	22.007	-0.125
	23	21.778	-0.395	23	22.007	-0.125
	24	21.758	-0.415	24	21.924	-0.208
	25	21.758	-0.415	25	21.986	-0.146
	26	21.737	-0.436	26	21.986	-0.146
	27	21.716	-0.457	27	21.965	-0.167
	28	21.716	-0.457	28	21.965	-0.167
	29	21.695	-0.478	29	21.965	-0.167
	30	21.695	-0.478	30	21.903	-0.229
	31	21.674	-0.499	31	21.965	-0.167
	32	21.674	-0.499	32	21.945	-0.187
	33	21.654	-0.519	33	21.882	-0.25
	34	21.654	-0.519	34	21.924	-0.208
	35	21.654	-0.519	35	21.945	-0.187
	36	21.633	-0.54	36	21.924	-0.208
	37	21.633	-0.54	37	21.903	-0.229
	38	21.571	-0.602	38	21.841	-0.291
	39	21.612	-0.561	39	21.903	-0.229
	40	21.633	-0.54	40	21.841	-0.291
	41	21.591	-0.582	41	21.882	-0.25
	42	21.529	-0.644	42	21.882	-0.25
	43	21.571	-0.602	43	21.882	-0.25
	44	21.571	-0.602	44	21.882	-0.25
	45	21.571	-0.602	45	21.82	-0.312
	46	21.55	-0.623	46	21.862	-0.27
	47	21.55	-0.623	47	21.882	-0.25
	48	21.508	-0.665	48	21.862	-0.27
	49	21.467	-0.706	49	21.799	-0.333
	50	21.487	-0.686	50	21.841	-0.291
	51	21.446	-0.727	51	21.841	-0.291
	52	21.508	-0.665	52	21.841	-0.291
	53	21.446	-0.727	53	21.841	-0.291
	54	21.487	-0.686	54	21.841	-0.291
	55	21.487	-0.686	55	21.82	-0.312
	56	21.467	-0.706	56	21.82	-0.312
	57	21.467	-0.706	57	21.82	-0.312
	58	21.446	-0.727	58	21.758	-0.374
	59	21.446	-0.727	59	21.778	-0.354
	60	21.383	-0.79	60	21.82	-0.312
	61	21.383	-0.79	61	21.799	-0.333
	62	21.363	-0.81	62	21.737	-0.395
	63	21.383	-0.79	63	21.799	-0.333
	64	21.363	-0.81	64	21.778	-0.354
	65	21.404	-0.769	65	21.778	-0.354
	66	21.404	-0.769	66	21.778	-0.354
	67	21.404	-0.769	67	21.778	-0.354
	68	21.383	-0.79	68	21.758	-0.374
	69	21.383	-0.79	69	21.716	-0.416
	70	21.383	-0.79	70	21.758	-0.374
	71	21.363	-0.81	71	21.695	-0.437
	72	21.363	-0.81	72	21.758	-0.374
	73	21.363	-0.81	73	21.695	-0.437
	74	21.342	-0.831	74	21.737	-0.395
	75	21.3	-0.873	75	21.758	-0.374
	76	21.342	-0.831	76	21.737	-0.395
	77	21.321	-0.852	77	21.737	-0.395
	78	21.321	-0.852	78	21.737	-0.395
	79	21.321	-0.852	79	21.716	-0.416
	80	21.321	-0.852	80	21.716	-0.416
	81	21.321	-0.852	81	21.695	-0.437
	82	21.3	-0.873	82	21.716	-0.416
	83	21.3	-0.873	83	21.716	-0.416
	84	21.28	-0.893	84	21.716	-0.416
	85	21.217	-0.956	85	21.716	-0.416
	86	21.238	-0.935	86	21.695	-0.437
	87	21.28	-0.893	87	21.695	-0.437
	88	21.259	-0.914	88	21.695	-0.437
	89	21.259	-0.914	89	21.695	-0.437
	90	21.259	-0.914	90	21.695	-0.437
	91	21.259	-0.914	91	21.716	-0.416
	92	21.238	-0.935	92	21.695	-0.437
	93	21.238	-0.935	93	21.633	-0.499
	94	21.238	-0.935	94	21.674	-0.458

	95	21.217	-0.956	95	21.674	-0.458
	96	21.217	-0.956	96	21.674	-0.458
	97	21.217	-0.956	97	21.674	-0.458
	98	21.196	-0.977	98	21.674	-0.458
	99	21.196	-0.977	99	21.674	-0.458
	100	21.196	-0.977	100	21.674	-0.458
	101	21.196	-0.977	101	21.654	-0.478
	102	21.196	-0.977	102	21.654	-0.478
	103	21.176	-0.997	103	21.654	-0.478
	104	21.176	-0.997	104	21.654	-0.478
	105	21.176	-0.997	105	21.654	-0.478
	106	21.176	-0.997	106	21.654	-0.478
	107	21.176	-0.997	107	21.654	-0.478
	108	21.155	-1.018	108	21.654	-0.478
	109	21.092	-1.081	109	21.633	-0.499

	110	21.155	-1.018	110	21.633	-0.499
	111	21.092	-1.081	111	21.633	-0.499
	112	21.155	-1.018	112	21.633	-0.499
	113	21.134	-1.039	113	21.633	-0.499
	114	21.134	-1.039	114	21.633	-0.499
	115	21.134	-1.039	115	21.612	-0.52
	116	21.072	-1.101	116	21.612	-0.52
	117	21.134	-1.039	117	21.612	-0.52
	118	21.072	-1.101	118	21.612	-0.52
	119	21.113	-1.06	119	21.612	-0.52
	120	21.113	-1.06	120	21.612	-0.52
Min			-1.101			-0.52
Max			0			0.02
Range			1.101			0.54

PAD LED670

Sample 4

Zone 1			Zone 2		
Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
0	21.924	0	0	21.737	0
1	21.903	-0.021	1	21.737	0
2	21.903	-0.021	2	21.716	-0.021
3	21.882	-0.042	3	21.716	-0.021
4	21.882	-0.042	4	21.716	-0.021
5	21.862	-0.062	5	21.695	-0.042
6	21.862	-0.062	6	21.695	-0.042
7	21.862	-0.062	7	21.695	-0.042
8	21.841	-0.083	8	21.695	-0.042
9	21.841	-0.083	9	21.695	-0.042
10	21.82	-0.104	10	21.674	-0.063
11	21.799	-0.125	11	21.674	-0.063
12	21.799	-0.125	12	21.674	-0.063
13	21.799	-0.125	13	21.633	-0.104
14	21.716	-0.208	14	21.612	-0.125
15	21.737	-0.187	15	21.674	-0.063
16	21.695	-0.229	16	21.654	-0.083
17	21.716	-0.208	17	21.674	-0.063
18	21.778	-0.146	18	21.633	-0.104
19	21.737	-0.187	19	21.633	-0.104
20	21.716	-0.208	20	21.633	-0.104
21	21.716	-0.208	21	21.612	-0.125
22	21.695	-0.229	22	21.612	-0.125
23	21.695	-0.229	23	21.612	-0.125
24	21.674	-0.25	24	21.612	-0.125
25	21.612	-0.312	25	21.612	-0.125
26	21.654	-0.27	26	21.591	-0.146
27	21.674	-0.25	27	21.591	-0.146
28	21.654	-0.27	28	21.591	-0.146
29	21.674	-0.25	29	21.591	-0.146
30	21.654	-0.27	30	21.55	-0.187
31	21.612	-0.312	31	21.508	-0.229
32	21.633	-0.291	32	21.571	-0.166
33	21.612	-0.312	33	21.508	-0.229
34	21.571	-0.353	34	21.571	-0.166
35	21.612	-0.312	35	21.508	-0.229
36	21.591	-0.333	36	21.55	-0.187
37	21.591	-0.333	37	21.55	-0.187
38	21.571	-0.353	38	21.55	-0.187
39	21.571	-0.353	39	21.55	-0.187
40	21.571	-0.353	40	21.55	-0.187
41	21.591	-0.333	41	21.55	-0.187
42	21.55	-0.374	42	21.529	-0.208
43	21.55	-0.374	43	21.529	-0.208
44	21.529	-0.395	44	21.529	-0.208
45	21.529	-0.395	45	21.529	-0.208
46	21.529	-0.395	46	21.529	-0.208
47	21.467	-0.457	47	21.55	-0.187
48	21.446	-0.478	48	21.529	-0.208
49	21.487	-0.437	49	21.467	-0.27
50	21.425	-0.499	50	21.508	-0.229
51	21.467	-0.457	51	21.55	-0.187
52	21.467	-0.457	52	21.508	-0.229
53	21.467	-0.457	53	21.508	-0.229
54	21.446	-0.478	54	21.508	-0.229
55	21.383	-0.541	55	21.508	-0.229
56	21.425	-0.499	56	21.508	-0.229
57	21.363	-0.561	57	21.508	-0.229
58	21.425	-0.499	58	21.446	-0.291
59	21.404	-0.52	59	21.487	-0.25
60	21.404	-0.52	60	21.487	-0.25
61	21.404	-0.52	61	21.487	-0.25
62	21.383	-0.541	62	21.487	-0.25
63	21.321	-0.603	63	21.487	-0.25
64	21.383	-0.541	64	21.487	-0.25
65	21.363	-0.561	65	21.467	-0.27
66	21.363	-0.561	66	21.467	-0.27
67	21.363	-0.561	67	21.467	-0.27
68	21.342	-0.582	68	21.467	-0.27
69	21.363	-0.561	69	21.467	-0.27
70	21.342	-0.582	70	21.467	-0.27
71	21.28	-0.644	71	21.446	-0.291
72	21.321	-0.603	72	21.446	-0.291
73	21.259	-0.665	73	21.446	-0.291
74	21.321	-0.603	74	21.467	-0.27
75	21.321	-0.603	75	21.446	-0.291
76	21.321	-0.603	76	21.446	-0.291
77	21.3	-0.624	77	21.446	-0.291
78	21.3	-0.624	78	21.383	-0.354
79	21.3	-0.624	79	21.425	-0.312
80	21.28	-0.644	80	21.425	-0.312
81	21.28	-0.644	81	21.467	-0.27
82	21.28	-0.644	82	21.425	-0.312
83	21.259	-0.665	83	21.363	-0.374
84	21.259	-0.665	84	21.383	-0.354
85	21.259	-0.665	85	21.404	-0.333
86	21.259	-0.665	86	21.425	-0.312
87	21.259	-0.665	87	21.404	-0.333
88	21.238	-0.686	88	21.404	-0.333
89	21.238	-0.686	89	21.404	-0.333
90	21.238	-0.686	90	21.342	-0.395
91	21.176	-0.748	91	21.404	-0.333
92	21.176	-0.748	92	21.404	-0.333
93	21.217	-0.707	93	21.404	-0.333
94	21.217	-0.707	94	21.383	-0.354

	95	21.217	-0.707	95	21.383	-0.354
	96	21.196	-0.728	96	21.383	-0.354
	97	21.196	-0.728	97	21.383	-0.354
	98	21.196	-0.728	98	21.383	-0.354
	99	21.196	-0.728	99	21.383	-0.354
	100	21.196	-0.728	100	21.383	-0.354
	101	21.134	-0.79	101	21.383	-0.354
	102	21.176	-0.748	102	21.321	-0.416
	103	21.176	-0.748	103	21.383	-0.354
	104	21.176	-0.748	104	21.363	-0.374
	105	21.176	-0.748	105	21.363	-0.374
	106	21.176	-0.748	106	21.363	-0.374
	107	21.176	-0.748	107	21.3	-0.437
	108	21.113	-0.811	108	21.363	-0.374
	109	21.155	-0.769	109	21.3	-0.437

	110	21.155	-0.769	110	21.363	-0.374
	111	21.155	-0.769	111	21.3	-0.437
	112	21.155	-0.769	112	21.321	-0.416
	113	21.092	-0.832	113	21.342	-0.395
	114	21.072	-0.852	114	21.342	-0.395
	115	21.072	-0.852	115	21.342	-0.395
	116	21.134	-0.79	116	21.342	-0.395
	117	21.134	-0.79	117	21.342	-0.395
	118	21.113	-0.811	118	21.342	-0.395
	119	21.113	-0.811	119	21.321	-0.416
	120	21.051	-0.873	120	21.321	-0.416
Min			-0.873			-0.437
Max			0			0
Range			0.873			0.437

PAD LED670						
Sample 5						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	21.529	0	0	21.321	0
	1	21.508	-0.021	1	21.321	0
	2	21.487	-0.042	2	21.321	0
	3	21.467	-0.062	3	21.363	0.042
	4	21.425	-0.104	4	21.3	-0.021
	5	21.425	-0.104	5	21.363	0.042
	6	21.425	-0.104	6	21.383	0.062
	7	21.404	-0.125	7	21.342	0.021
	8	21.425	-0.104	8	21.342	0.021
	9	21.404	-0.125	9	21.28	-0.041
	10	21.342	-0.187	10	21.321	0
	11	21.383	-0.146	11	21.321	0
	12	21.363	-0.166	12	21.3	-0.021
	13	21.342	-0.187	13	21.238	-0.083
	14	21.259	-0.27	14	21.3	-0.021
	15	21.28	-0.249	15	21.238	-0.083
	16	21.259	-0.27	16	21.28	-0.041
	17	21.3	-0.229	17	21.217	-0.104
	18	21.3	-0.229	18	21.28	-0.041
	19	21.28	-0.249	19	21.28	-0.041
	20	21.259	-0.27	20	21.259	-0.062
	21	21.259	-0.27	21	21.259	-0.062
	22	21.259	-0.27	22	21.259	-0.062
	23	21.217	-0.312	23	21.259	-0.062
	24	21.196	-0.333	24	21.238	-0.083
	25	21.176	-0.353	25	21.238	-0.083
	26	21.155	-0.374	26	21.176	-0.145
	27	21.134	-0.395	27	21.238	-0.083
	28	21.134	-0.395	28	21.217	-0.104
	29	21.155	-0.374	29	21.217	-0.104
	30	21.092	-0.437	30	21.217	-0.104
	31	21.092	-0.437	31	21.217	-0.104
	32	21.051	-0.478	32	21.196	-0.125
	33	21.092	-0.437	33	21.134	-0.187
	34	21.009	-0.52	34	21.196	-0.125
	35	21.051	-0.478	35	21.196	-0.125
	36	21.051	-0.478	36	21.176	-0.145
	37	21.03	-0.499	37	21.176	-0.145
	38	21.009	-0.52	38	21.176	-0.145
	39	21.009	-0.52	39	21.176	-0.145
	40	20.989	-0.54	40	21.176	-0.145
	41	20.989	-0.54	41	21.134	-0.187
	42	20.989	-0.54	42	21.092	-0.229
	43	20.968	-0.561	43	21.155	-0.166
	44	20.947	-0.582	44	21.092	-0.229
	45	20.947	-0.582	45	21.155	-0.166
	46	20.864	-0.665	46	21.155	-0.166
	47	20.905	-0.624	47	21.134	-0.187
	48	20.885	-0.644	48	21.134	-0.187
	49	20.843	-0.686	49	21.134	-0.187
	50	20.801	-0.728	50	21.134	-0.187
	51	20.864	-0.665	51	21.134	-0.187
	52	20.843	-0.686	52	21.134	-0.187
	53	20.822	-0.707	53	21.113	-0.208
	54	20.822	-0.707	54	21.113	-0.208
	55	20.822	-0.707	55	21.113	-0.208
	56	20.801	-0.728	56	21.113	-0.208
	57	20.801	-0.728	57	21.113	-0.208
	58	20.801	-0.728	58	21.113	-0.208
	59	20.781	-0.748	59	21.113	-0.208
	60	20.76	-0.769	60	21.092	-0.229
	61	20.739	-0.79	61	21.092	-0.229
	62	20.739	-0.79	62	21.092	-0.229
	63	20.739	-0.79	63	21.092	-0.229
	64	20.718	-0.811	64	21.092	-0.229
	65	20.698	-0.831	65	21.092	-0.229
	66	20.677	-0.852	66	21.092	-0.229
	67	20.677	-0.852	67	21.072	-0.249
	68	20.677	-0.852	68	21.072	-0.249
	69	20.656	-0.873	69	21.072	-0.249
	70	20.656	-0.873	70	21.072	-0.249
	71	20.656	-0.873	71	21.072	-0.249
	72	20.656	-0.873	72	21.072	-0.249
	73	20.635	-0.894	73	21.072	-0.249
	74	20.614	-0.915	74	21.072	-0.249
	75	20.594	-0.935	75	21.051	-0.27
	76	20.594	-0.935	76	21.051	-0.27
	77	20.573	-0.956	77	21.051	-0.27
	78	20.573	-0.956	78	21.051	-0.27
	79	20.552	-0.977	79	21.072	-0.249
	80	20.552	-0.977	80	21.009	-0.312
	81	20.552	-0.977	81	21.072	-0.249
	82	20.531	-0.998	82	21.009	-0.312
	83	20.531	-0.998	83	20.989	-0.332
	84	20.51	-1.019	84	21.03	-0.291
	85	20.51	-1.019	85	20.968	-0.353
	86	20.49	-1.039	86	21.03	-0.291
	87	20.469	-1.06	87	21.03	-0.291
	88	20.448	-1.081	88	21.03	-0.291
	89	20.448	-1.081	89	21.03	-0.291
	90	20.427	-1.102	90	20.968	-0.353
	91	20.407	-1.122	91	20.947	-0.374
	92	20.427	-1.102	92	21.009	-0.312
	93	20.427	-1.102	93	20.989	-0.332
	94	20.427	-1.102	94	20.947	-0.374

	95	20.427	-1.102	95	20.968	-0.353
	96	20.407	-1.122	96	21.009	-0.312
	97	20.386	-1.143	97	21.009	-0.312
	98	20.365	-1.164	98	21.009	-0.312
	99	20.365	-1.164	99	21.009	-0.312
	100	20.365	-1.164	100	21.009	-0.312
	101	20.344	-1.185	101	21.009	-0.312
	102	20.344	-1.185	102	20.989	-0.332
	103	20.344	-1.185	103	20.947	-0.374
	104	20.323	-1.206	104	20.989	-0.332
	105	20.323	-1.206	105	20.926	-0.395
	106	20.323	-1.206	106	20.989	-0.332
	107	20.261	-1.268	107	20.989	-0.332
	108	20.24	-1.289	108	20.989	-0.332
	109	20.282	-1.247	109	20.989	-0.332

	110	20.219	-1.31	110	20.989	-0.332
	111	20.282	-1.247	111	20.989	-0.332
	112	20.282	-1.247	112	20.989	-0.332
	113	20.261	-1.268	113	20.989	-0.332
	114	20.261	-1.268	114	20.989	-0.332
	115	20.261	-1.268	115	20.989	-0.332
	116	20.261	-1.268	116	20.989	-0.332
	117	20.261	-1.268	117	20.989	-0.332
	118	20.261	-1.268	118	20.968	-0.353
	119	20.24	-1.289	119	20.968	-0.353
	120	20.24	-1.289	120	20.968	-0.353
Min			-1.31			-0.395
Max			0			0.062
Range			1.31			0.457

Raw temperature data: PAD SD50

PAD SD50						
Sample 1						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	22.298	0	0	22.215	0
	1	22.298	0	1	22.215	0
	2	22.277	-0.021	2	22.215	0
	3	22.298	0	3	22.215	0
	4	22.298	0	4	22.215	0
	5	22.298	0	5	22.236	0.021
	6	22.298	0	6	22.215	0
	7	22.319	0.021	7	22.215	0
	8	22.298	0	8	22.277	0.062
	9	22.34	0.042	9	22.298	0.083
	10	22.34	0.042	10	22.277	0.062
	11	22.36	0.062	11	22.34	0.125
	12	22.381	0.083	12	22.36	0.145
	13	22.36	0.062	13	22.381	0.166
	14	22.423	0.125	14	22.402	0.187
	15	22.443	0.145	15	22.423	0.208
	16	22.443	0.145	16	22.443	0.228
	17	22.464	0.166	17	22.423	0.208
	18	22.443	0.145	18	22.464	0.249
	19	22.464	0.166	19	22.506	0.291
	20	22.527	0.229	20	22.527	0.312
	21	22.527	0.229	21	22.547	0.332
	22	22.547	0.249	22	22.568	0.353
	23	22.547	0.249	23	22.589	0.374
	24	22.568	0.27	24	22.589	0.374
	25	22.589	0.291	25	22.589	0.374
	26	22.589	0.291	26	22.631	0.416
	27	22.61	0.312	27	22.61	0.395
	28	22.61	0.312	28	22.651	0.436
	29	22.631	0.333	29	22.672	0.457
	30	22.589	0.291	30	22.672	0.457
	31	22.651	0.353	31	22.672	0.457
	32	22.651	0.353	32	22.672	0.457
	33	22.631	0.333	33	22.693	0.478
	34	22.672	0.374	34	22.693	0.478
	35	22.672	0.374	35	22.714	0.499
	36	22.693	0.395	36	22.734	0.519
	37	22.693	0.395	37	22.734	0.519
	38	22.714	0.416	38	22.734	0.519
	39	22.714	0.416	39	22.714	0.499
	40	22.693	0.395	40	22.755	0.54
	41	22.714	0.416	41	22.755	0.54
	42	22.672	0.374	42	22.776	0.561
	43	22.734	0.436	43	22.776	0.561
	44	22.755	0.457	44	22.776	0.561
	45	22.755	0.457	45	22.776	0.561
	46	22.755	0.457	46	22.755	0.54
	47	22.776	0.478	47	22.797	0.582
	48	22.755	0.457	48	22.818	0.603
	49	22.797	0.499	49	22.818	0.603
	50	22.797	0.499	50	22.818	0.603
	51	22.797	0.499	51	22.838	0.623
	52	22.797	0.499	52	22.838	0.623
	53	22.818	0.52	53	22.818	0.603
	54	22.818	0.52	54	22.859	0.644
	55	22.818	0.52	55	22.88	0.665
	56	22.838	0.54	56	22.901	0.686
	57	22.859	0.561	57	22.901	0.686
	58	22.859	0.561	58	22.901	0.686
	59	22.859	0.561	59	22.901	0.686
	60	22.859	0.561	60	22.88	0.665
	61	22.859	0.561	61	22.901	0.686
	62	22.818	0.52	62	22.922	0.707
	63	22.818	0.52	63	22.942	0.727
	64	22.838	0.54	64	22.942	0.727
	65	22.88	0.582	65	22.942	0.727
	66	22.88	0.582	66	22.942	0.727
	67	22.88	0.582	67	22.942	0.727
	68	22.859	0.561	68	22.942	0.727
	69	22.88	0.582	69	22.942	0.727
	70	22.901	0.603	70	22.942	0.727
	71	22.922	0.624	71	22.942	0.727
	72	22.922	0.624	72	22.942	0.727
	73	22.922	0.624	73	22.963	0.748
	74	22.922	0.624	74	22.963	0.748
	75	22.942	0.644	75	22.963	0.748
	76	22.963	0.665	76	22.963	0.748
	77	22.963	0.665	77	22.984	0.769
	78	22.963	0.665	78	22.984	0.769
	79	22.963	0.665	79	23.005	0.79
	80	22.963	0.665	80	22.984	0.769
	81	23.005	0.707	81	23.005	0.79
	82	22.984	0.686	82	23.005	0.79
	83	22.963	0.665	83	23.025	0.81
	84	22.963	0.665	84	23.025	0.81
	85	22.963	0.665	85	23.025	0.81
	86	22.984	0.686	86	23.046	0.831
	87	22.984	0.686	87	23.046	0.831
	88	23.005	0.707	88	23.067	0.852

	89	23.005	0.707	89	23.067	0.852
	90	23.005	0.707	90	23.067	0.852
	91	23.025	0.727	91	23.067	0.852
	92	23.025	0.727	92	23.046	0.831
	93	22.984	0.686	93	23.088	0.873
	94	23.025	0.727	94	23.109	0.894
	95	23.025	0.727	95	23.067	0.852
	96	23.046	0.748	96	23.109	0.894
	97	23.046	0.748	97	23.088	0.873
	98	23.046	0.748	98	23.109	0.894
	99	23.067	0.769	99	23.129	0.914
	100	23.067	0.769	100	23.15	0.935
	101	23.046	0.748	101	23.129	0.914
	102	23.067	0.769	102	23.109	0.894
	103	23.025	0.727	103	23.088	0.873
	104	23.067	0.769	104	23.109	0.894
	105	23.025	0.727	105	23.15	0.935
	106	23.067	0.769	106	23.109	0.894

	107	23.067	0.769	107	23.129	0.914
	108	23.067	0.769	108	23.129	0.914
	109	23.067	0.769	109	23.129	0.914
	110	23.088	0.79	110	23.109	0.894
	111	23.088	0.79	111	23.129	0.914
	112	23.046	0.748	112	23.109	0.894
	113	23.088	0.79	113	23.129	0.914
	114	23.088	0.79	114	23.129	0.914
	115	23.067	0.769	115	23.129	0.914
	116	23.046	0.748	116	23.129	0.914
	117	23.067	0.769	117	23.109	0.894
	118	23.109	0.811	118	23.088	0.873
	119	23.109	0.811	119	23.088	0.873
	120	23.109	0.811	120	23.129	0.914
Min			-0.021			0
Max			0.811			0.935
Range			0.832			0.935

PAD SD50						
Sample 2						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	22.215	0	0	22.506	0
	1	22.215	0	1	22.485	-0.021
	2	22.194	-0.021	2	22.485	-0.021
	3	22.194	-0.021	3	22.485	-0.021
	4	22.173	-0.042	4	22.506	0
	5	22.194	-0.021	5	22.506	0
	6	22.173	-0.042	6	22.527	0.021
	7	22.173	-0.042	7	22.527	0.021
	8	22.215	0	8	22.547	0.041
	9	22.236	0.021	9	22.568	0.062
	10	22.194	-0.021	10	22.589	0.083
	11	22.215	0	11	22.568	0.062
	12	22.256	0.041	12	22.61	0.104
	13	22.256	0.041	13	22.61	0.104
	14	22.236	0.021	14	22.631	0.125
	15	22.256	0.041	15	22.651	0.145
	16	22.298	0.083	16	22.631	0.125
	17	22.319	0.104	17	22.672	0.166
	18	22.319	0.104	18	22.651	0.145
	19	22.34	0.125	19	22.672	0.166
	20	22.34	0.125	20	22.672	0.166
	21	22.36	0.145	21	22.714	0.208
	22	22.34	0.125	22	22.734	0.228
	23	22.381	0.166	23	22.755	0.249
	24	22.36	0.145	24	22.776	0.27
	25	22.36	0.145	25	22.797	0.291
	26	22.402	0.187	26	22.818	0.312
	27	22.402	0.187	27	22.797	0.291
	28	22.402	0.187	28	22.838	0.332
	29	22.423	0.208	29	22.859	0.353
	30	22.443	0.228	30	22.88	0.374
	31	22.443	0.228	31	22.859	0.353
	32	22.464	0.249	32	22.901	0.395
	33	22.464	0.249	33	22.901	0.395
	34	22.485	0.27	34	22.922	0.416
	35	22.485	0.27	35	22.922	0.416
	36	22.485	0.27	36	22.922	0.416
	37	22.485	0.27	37	22.942	0.436
	38	22.485	0.27	38	22.942	0.436
	39	22.506	0.291	39	22.942	0.436
	40	22.464	0.249	40	22.963	0.457
	41	22.485	0.27	41	22.963	0.457
	42	22.506	0.291	42	22.963	0.457
	43	22.527	0.312	43	22.963	0.457
	44	22.527	0.312	44	22.963	0.457
	45	22.547	0.332	45	22.963	0.457
	46	22.547	0.332	46	22.942	0.436
	47	22.527	0.312	47	22.942	0.436
	48	22.568	0.353	48	22.984	0.478
	49	22.589	0.374	49	22.963	0.457
	50	22.61	0.395	50	22.984	0.478
	51	22.61	0.395	51	23.005	0.499
	52	22.631	0.416	52	23.025	0.519
	53	22.631	0.416	53	23.005	0.499
	54	22.589	0.374	54	23.025	0.519
	55	22.631	0.416	55	23.025	0.519
	56	22.631	0.416	56	23.025	0.519
	57	22.631	0.416	57	23.046	0.54
	58	22.631	0.416	58	23.046	0.54
	59	22.589	0.374	59	23.046	0.54
	60	22.631	0.416	60	23.046	0.54
	61	22.631	0.416	61	23.046	0.54
	62	22.631	0.416	62	23.046	0.54
	63	22.631	0.416	63	23.067	0.561
	64	22.631	0.416	64	23.088	0.582
	65	22.631	0.416	65	23.088	0.582
	66	22.589	0.374	66	23.088	0.582
	67	22.631	0.416	67	23.109	0.603
	68	22.631	0.416	68	23.109	0.603
	69	22.631	0.416	69	23.109	0.603
	70	22.61	0.395	70	23.109	0.603
	71	22.631	0.416	71	23.088	0.582
	72	22.631	0.416	72	23.129	0.623
	73	22.631	0.416	73	23.129	0.623
	74	22.651	0.436	74	23.129	0.623
	75	22.631	0.416	75	23.15	0.644
	76	22.651	0.436	76	23.15	0.644
	77	22.631	0.416	77	23.15	0.644
	78	22.651	0.436	78	23.15	0.644
	79	22.651	0.436	79	23.15	0.644
	80	22.651	0.436	80	23.15	0.644
	81	22.651	0.436	81	23.15	0.644
	82	22.672	0.457	82	23.15	0.644
	83	22.672	0.457	83	23.15	0.644
	84	22.651	0.436	84	23.15	0.644
	85	22.672	0.457	85	23.15	0.644
	86	22.693	0.478	86	23.15	0.644
	87	22.672	0.457	87	23.15	0.644
	88	22.672	0.457	88	23.15	0.644
	89	22.651	0.436	89	23.171	0.665
	90	22.651	0.436	90	23.171	0.665
	91	22.631	0.416	91	23.192	0.686
	92	22.693	0.478	92	23.192	0.686
	93	22.693	0.478	93	23.192	0.686
	94	22.693	0.478	94	23.213	0.707

	95	22.651	0.436	95	23.213	0.707
	96	22.672	0.457	96	23.213	0.707
	97	22.672	0.457	97	23.213	0.707
	98	22.651	0.436	98	23.192	0.686
	99	22.693	0.478	99	23.171	0.665
	100	22.693	0.478	100	23.192	0.686
	101	22.672	0.457	101	23.233	0.727
	102	22.672	0.457	102	23.233	0.727
	103	22.714	0.499	103	23.233	0.727
	104	22.714	0.499	104	23.233	0.727
	105	22.714	0.499	105	23.233	0.727
	106	22.714	0.499	106	23.254	0.748
	107	22.714	0.499	107	23.233	0.727
	108	22.714	0.499	108	23.254	0.748
	109	22.714	0.499	109	23.254	0.748

	110	22.672	0.457	110	23.233	0.727
	111	22.714	0.499	111	23.254	0.748
	112	22.714	0.499	112	23.233	0.727
	113	22.714	0.499	113	23.275	0.769
	114	22.714	0.499	114	23.275	0.769
	115	22.714	0.499	115	23.275	0.769
	116	22.714	0.499	116	23.275	0.769
	117	22.714	0.499	117	23.275	0.769
	118	22.714	0.499	118	23.296	0.79
	119	22.714	0.499	119	23.275	0.769
	120	22.714	0.499	120	23.275	0.769
Min			-0.042			-0.021
Max			0.499			0.79
Range			0.541			0.811

PAD SD50						
Sample 3						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	20.386	0	0	21.404	0
	1	20.407	0.021	1	21.446	0.042
	2	20.448	0.062	2	21.508	0.104
	3	20.531	0.145	3	21.508	0.104
	4	20.531	0.145	4	21.612	0.208
	5	20.594	0.208	5	21.674	0.27
	6	20.635	0.249	6	21.737	0.333
	7	20.677	0.291	7	21.778	0.374
	8	20.718	0.332	8	21.82	0.416
	9	20.76	0.374	9	21.862	0.458
	10	20.801	0.415	10	21.903	0.499
	11	20.843	0.457	11	21.945	0.541
	12	20.843	0.457	12	21.924	0.52
	13	20.926	0.54	13	22.007	0.603
	14	20.926	0.54	14	22.028	0.624
	15	20.989	0.603	15	22.069	0.665
	16	21.051	0.665	16	22.111	0.707
	17	21.051	0.665	17	22.132	0.728
	18	21.092	0.706	18	22.152	0.748
	19	21.134	0.748	19	22.194	0.79
	20	21.176	0.79	20	22.173	0.769
	21	21.176	0.79	21	22.236	0.832
	22	21.238	0.852	22	22.215	0.811
	23	21.28	0.894	23	22.277	0.873
	24	21.3	0.914	24	22.298	0.894
	25	21.3	0.914	25	22.319	0.915
	26	21.363	0.977	26	22.34	0.936
	27	21.363	0.977	27	22.36	0.956
	28	21.425	1.039	28	22.381	0.977
	29	21.404	1.018	29	22.402	0.998
	30	21.467	1.081	30	22.423	1.019
	31	21.487	1.101	31	22.443	1.039
	32	21.508	1.122	32	22.443	1.039
	33	21.529	1.143	33	22.464	1.06
	34	21.55	1.164	34	22.485	1.081
	35	21.571	1.185	35	22.506	1.102
	36	21.591	1.205	36	22.506	1.102
	37	21.633	1.247	37	22.527	1.123
	38	21.654	1.268	38	22.547	1.143
	39	21.633	1.247	39	22.568	1.164
	40	21.695	1.309	40	22.568	1.164
	41	21.716	1.33	41	22.589	1.185
	42	21.737	1.351	42	22.61	1.206
	43	21.737	1.351	43	22.631	1.227
	44	21.778	1.392	44	22.589	1.185
	45	21.799	1.413	45	22.651	1.247
	46	21.841	1.455	46	22.631	1.227
	47	21.862	1.476	47	22.672	1.268
	48	21.882	1.496	48	22.672	1.268
	49	21.903	1.517	49	22.651	1.247
	50	21.903	1.517	50	22.714	1.31
	51	21.924	1.538	51	22.714	1.31
	52	21.945	1.559	52	22.734	1.33
	53	21.965	1.579	53	22.755	1.351
	54	21.986	1.6	54	22.755	1.351
	55	22.028	1.642	55	22.734	1.33
	56	22.049	1.663	56	22.776	1.372
	57	22.069	1.683	57	22.797	1.393
	58	22.09	1.704	58	22.755	1.351
	59	22.111	1.725	59	22.818	1.414
	60	22.132	1.746	60	22.838	1.434
	61	22.132	1.746	61	22.838	1.434
	62	22.173	1.787	62	22.859	1.455
	63	22.173	1.787	63	22.88	1.476
	64	22.215	1.829	64	22.901	1.497
	65	22.236	1.85	65	22.901	1.497
	66	22.256	1.87	66	22.922	1.518
	67	22.277	1.891	67	22.922	1.518
	68	22.319	1.933	68	22.942	1.538
	69	22.34	1.954	69	22.942	1.538
	70	22.36	1.974	70	22.963	1.559
	71	22.36	1.974	71	22.963	1.559
	72	22.34	1.954	72	22.963	1.559
	73	22.34	1.954	73	22.963	1.559
	74	22.402	2.016	74	22.922	1.518
	75	22.381	1.995	75	22.963	1.559
	76	22.402	2.016	76	22.963	1.559
	77	22.402	2.016	77	22.942	1.538
	78	22.464	2.078	78	22.984	1.58
	79	22.485	2.099	79	22.984	1.58
	80	22.527	2.141	80	23.005	1.601
	81	22.527	2.141	81	22.984	1.58
	82	22.527	2.141	82	22.963	1.559
	83	22.527	2.141	83	22.942	1.538
	84	22.568	2.182	84	23.005	1.601
	85	22.589	2.203	85	22.963	1.559
	86	22.589	2.203	86	23.025	1.621
	87	22.651	2.265	87	23.025	1.621
	88	22.651	2.265	88	23.025	1.621
	89	22.672	2.286	89	23.046	1.642
	90	22.672	2.286	90	23.046	1.642
	91	22.693	2.307	91	23.067	1.663
	92	22.672	2.286	92	23.025	1.621
	93	22.734	2.348	93	23.067	1.663
	94	22.714	2.328	94	23.025	1.621

	95	22.776	2.39	95	23.067	1.663
	96	22.797	2.411	96	23.088	1.684
	97	22.797	2.411	97	23.109	1.705
	98	22.838	2.452	98	23.109	1.705
	99	22.88	2.494	99	23.129	1.725
	100	22.859	2.473	100	23.129	1.725
	101	22.922	2.536	101	23.129	1.725
	102	22.901	2.515	102	23.129	1.725
	103	22.963	2.577	103	23.129	1.725
	104	22.963	2.577	104	23.129	1.725
	105	22.984	2.598	105	23.15	1.746
	106	22.984	2.598	106	23.15	1.746
	107	23.005	2.619	107	23.15	1.746
	108	23.025	2.639	108	23.15	1.746
	109	23.067	2.681	109	23.129	1.725

	110	23.046	2.66	110	23.171	1.767
	111	23.067	2.681	111	23.171	1.767
	112	23.067	2.681	112	23.171	1.767
	113	23.067	2.681	113	23.192	1.788
	114	23.088	2.702	114	23.192	1.788
	115	23.109	2.723	115	23.192	1.788
	116	23.109	2.723	116	23.192	1.788
	117	23.129	2.743	117	23.192	1.788
	118	23.088	2.702	118	23.171	1.767
	119	23.129	2.743	119	23.213	1.809
	120	23.129	2.743	120	23.213	1.809
Min			0			0
Max			2.743			1.809
Range			2.743			1.809

PAD SD50						
Sample 4						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	21.508	0	0	22.007	0
	1	21.508	0	1	21.986	-0.021
	2	21.467	-0.041	2	21.986	-0.021
	3	21.508	0	3	21.986	-0.021
	4	21.529	0.021	4	21.965	-0.042
	5	21.55	0.042	5	22.007	0
	6	21.55	0.042	6	21.986	-0.021
	7	21.571	0.063	7	22.007	0
	8	21.571	0.063	8	22.028	0.021
	9	21.591	0.083	9	22.028	0.021
	10	21.612	0.104	10	22.007	0
	11	21.612	0.104	11	22.049	0.042
	12	21.633	0.125	12	22.069	0.062
	13	21.654	0.146	13	22.049	0.042
	14	21.674	0.166	14	22.111	0.104
	15	21.695	0.187	15	22.111	0.104
	16	21.716	0.208	16	22.111	0.104
	17	21.716	0.208	17	22.111	0.104
	18	21.737	0.229	18	22.132	0.125
	19	21.737	0.229	19	22.132	0.125
	20	21.778	0.27	20	22.152	0.145
	21	21.799	0.291	21	22.152	0.145
	22	21.82	0.312	22	22.173	0.166
	23	21.841	0.333	23	22.173	0.166
	24	21.862	0.354	24	22.173	0.166
	25	21.882	0.374	25	22.194	0.187
	26	21.903	0.395	26	22.215	0.208
	27	21.924	0.416	27	22.215	0.208
	28	21.965	0.457	28	22.236	0.229
	29	21.965	0.457	29	22.215	0.208
	30	21.986	0.478	30	22.194	0.187
	31	22.007	0.499	31	22.256	0.249
	32	22.007	0.499	32	22.256	0.249
	33	22.028	0.52	33	22.277	0.27
	34	22.049	0.541	34	22.236	0.229
	35	22.09	0.582	35	22.298	0.291
	36	22.09	0.582	36	22.298	0.291
	37	22.111	0.603	37	22.319	0.312
	38	22.132	0.624	38	22.277	0.27
	39	22.132	0.624	39	22.319	0.312
	40	22.173	0.665	40	22.34	0.333
	41	22.152	0.644	41	22.34	0.333
	42	22.194	0.686	42	22.36	0.353
	43	22.215	0.707	43	22.36	0.353
	44	22.236	0.728	44	22.36	0.353
	45	22.236	0.728	45	22.381	0.374
	46	22.256	0.748	46	22.381	0.374
	47	22.256	0.748	47	22.381	0.374
	48	22.256	0.748	48	22.402	0.395
	49	22.277	0.769	49	22.402	0.395
	50	22.277	0.769	50	22.423	0.416
	51	22.298	0.79	51	22.381	0.374
	52	22.298	0.79	52	22.423	0.416
	53	22.319	0.811	53	22.423	0.416
	54	22.319	0.811	54	22.423	0.416
	55	22.34	0.832	55	22.381	0.374
	56	22.34	0.832	56	22.443	0.436
	57	22.381	0.873	57	22.443	0.436
	58	22.36	0.852	58	22.443	0.436
	59	22.319	0.811	59	22.443	0.436
	60	22.381	0.873	60	22.464	0.457
	61	22.381	0.873	61	22.464	0.457
	62	22.381	0.873	62	22.464	0.457
	63	22.402	0.894	63	22.464	0.457
	64	22.423	0.915	64	22.485	0.478
	65	22.423	0.915	65	22.485	0.478
	66	22.464	0.956	66	22.485	0.478
	67	22.464	0.956	67	22.485	0.478
	68	22.464	0.956	68	22.485	0.478
	69	22.443	0.935	69	22.506	0.499
	70	22.464	0.956	70	22.506	0.499
	71	22.485	0.977	71	22.506	0.499
	72	22.506	0.998	72	22.506	0.499
	73	22.506	0.998	73	22.527	0.52
	74	22.506	0.998	74	22.527	0.52
	75	22.527	1.019	75	22.485	0.478
	76	22.547	1.039	76	22.506	0.499
	77	22.547	1.039	77	22.485	0.478
	78	22.547	1.039	78	22.527	0.52
	79	22.547	1.039	79	22.527	0.52
	80	22.547	1.039	80	22.506	0.499
	81	22.547	1.039	81	22.527	0.52
	82	22.589	1.081	82	22.547	0.54
	83	22.589	1.081	83	22.547	0.54
	84	22.61	1.102	84	22.547	0.54
	85	22.61	1.102	85	22.527	0.52
	86	22.61	1.102	86	22.568	0.561
	87	22.61	1.102	87	22.547	0.54
	88	22.631	1.123	88	22.568	0.561
	89	22.61	1.102	89	22.568	0.561
	90	22.631	1.123	90	22.568	0.561
	91	22.631	1.123	91	22.547	0.54
	92	22.651	1.143	92	22.568	0.561
	93	22.672	1.164	93	22.527	0.52
	94	22.672	1.164	94	22.589	0.582

	95	22.672	1.164	95	22.589	0.582
	96	22.672	1.164	96	22.589	0.582
	97	22.693	1.185	97	22.589	0.582
	98	22.693	1.185	98	22.589	0.582
	99	22.693	1.185	99	22.568	0.561
	100	22.693	1.185	100	22.61	0.603
	101	22.693	1.185	101	22.568	0.561
	102	22.714	1.206	102	22.61	0.603
	103	22.714	1.206	103	22.61	0.603
	104	22.734	1.226	104	22.61	0.603
	105	22.734	1.226	105	22.61	0.603
	106	22.693	1.185	106	22.61	0.603
	107	22.714	1.206	107	22.61	0.603
	108	22.734	1.226	108	22.61	0.603
	109	22.693	1.185	109	22.61	0.603

	110	22.734	1.226	110	22.61	0.603
	111	22.714	1.206	111	22.61	0.603
	112	22.755	1.247	112	22.61	0.603
	113	22.755	1.247	113	22.61	0.603
	114	22.755	1.247	114	22.61	0.603
	115	22.755	1.247	115	22.631	0.624
	116	22.776	1.268	116	22.631	0.624
	117	22.776	1.268	117	22.631	0.624
	118	22.776	1.268	118	22.631	0.624
	119	22.776	1.268	119	22.631	0.624
	120	22.776	1.268	120	22.631	0.624
Min			-0.041			-0.042
Max			1.268			0.624
Range			1.309			0.666

PAD SD50						
Sample 5						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	20.594	0	0	20.864	0
	1	20.531	-0.063	1	20.864	0
	2	20.594	0	2	20.905	0.041
	3	20.552	-0.042	3	20.926	0.062
	4	20.594	0	4	20.947	0.083
	5	20.614	0.02	5	20.968	0.104
	6	20.614	0.02	6	20.989	0.125
	7	20.614	0.02	7	21.009	0.145
	8	20.656	0.062	8	21.009	0.145
	9	20.677	0.083	9	21.051	0.187
	10	20.698	0.104	10	21.092	0.228
	11	20.718	0.124	11	21.113	0.249
	12	20.698	0.104	12	21.134	0.27
	13	20.76	0.166	13	21.155	0.291
	14	20.739	0.145	14	21.176	0.312
	15	20.801	0.207	15	21.155	0.291
	16	20.801	0.207	16	21.196	0.332
	17	20.76	0.166	17	21.217	0.353
	18	20.801	0.207	18	21.217	0.353
	19	20.843	0.249	19	21.217	0.353
	20	20.843	0.249	20	21.259	0.395
	21	20.864	0.27	21	21.28	0.416
	22	20.885	0.291	22	21.3	0.436
	23	20.864	0.27	23	21.321	0.457
	24	20.905	0.311	24	21.321	0.457
	25	20.905	0.311	25	21.342	0.478
	26	20.885	0.291	26	21.363	0.499
	27	20.905	0.311	27	21.363	0.499
	28	20.968	0.374	28	21.383	0.519
	29	20.968	0.374	29	21.383	0.519
	30	20.989	0.395	30	21.404	0.54
	31	20.989	0.395	31	21.425	0.561
	32	21.009	0.415	32	21.425	0.561
	33	20.968	0.374	33	21.446	0.582
	34	20.989	0.395	34	21.425	0.561
	35	21.072	0.478	35	21.446	0.582
	36	21.051	0.457	36	21.425	0.561
	37	21.051	0.457	37	21.487	0.623
	38	21.072	0.478	38	21.508	0.644
	39	21.072	0.478	39	21.508	0.644
	40	21.072	0.478	40	21.529	0.665
	41	21.072	0.478	41	21.529	0.665
	42	21.072	0.478	42	21.55	0.686
	43	21.134	0.54	43	21.55	0.686
	44	21.155	0.561	44	21.529	0.665
	45	21.155	0.561	45	21.571	0.707
	46	21.176	0.582	46	21.591	0.727
	47	21.176	0.582	47	21.591	0.727
	48	21.196	0.602	48	21.612	0.748
	49	21.196	0.602	49	21.612	0.748
	50	21.155	0.561	50	21.612	0.748
	51	21.217	0.623	51	21.612	0.748
	52	21.217	0.623	52	21.591	0.727
	53	21.217	0.623	53	21.654	0.79
	54	21.238	0.644	54	21.654	0.79
	55	21.238	0.644	55	21.654	0.79
	56	21.259	0.665	56	21.674	0.81
	57	21.238	0.644	57	21.674	0.81
	58	21.259	0.665	58	21.674	0.81
	59	21.238	0.644	59	21.695	0.831
	60	21.238	0.644	60	21.695	0.831
	61	21.28	0.686	61	21.716	0.852
	62	21.3	0.706	62	21.716	0.852
	63	21.259	0.665	63	21.716	0.852
	64	21.3	0.706	64	21.737	0.873
	65	21.321	0.727	65	21.737	0.873
	66	21.321	0.727	66	21.737	0.873
	67	21.321	0.727	67	21.758	0.894
	68	21.321	0.727	68	21.758	0.894
	69	21.342	0.748	69	21.758	0.894
	70	21.342	0.748	70	21.737	0.873
	71	21.363	0.769	71	21.778	0.914
	72	21.383	0.789	72	21.737	0.873
	73	21.383	0.789	73	21.799	0.935
	74	21.342	0.748	74	21.799	0.935
	75	21.383	0.789	75	21.799	0.935
	76	21.383	0.789	76	21.82	0.956
	77	21.404	0.81	77	21.82	0.956
	78	21.404	0.81	78	21.799	0.935
	79	21.404	0.81	79	21.82	0.956
	80	21.425	0.831	80	21.841	0.977
	81	21.383	0.789	81	21.841	0.977
	82	21.425	0.831	82	21.841	0.977
	83	21.446	0.852	83	21.862	0.998
	84	21.446	0.852	84	21.82	0.956
	85	21.446	0.852	85	21.862	0.998
	86	21.446	0.852	86	21.82	0.956
	87	21.446	0.852	87	21.841	0.977
	88	21.467	0.873	88	21.862	0.998
	89	21.467	0.873	89	21.882	1.018
	90	21.467	0.873	90	21.882	1.018
	91	21.467	0.873	91	21.882	1.018
	92	21.467	0.873	92	21.882	1.018
	93	21.467	0.873	93	21.903	1.039
	94	21.467	0.873	94	21.903	1.039

	95	21.467	0.873	95	21.903	1.039
	96	21.446	0.852	96	21.903	1.039
	97	21.467	0.873	97	21.924	1.06
	98	21.487	0.893	98	21.924	1.06
	99	21.487	0.893	99	21.903	1.039
	100	21.487	0.893	100	21.882	1.018
	101	21.487	0.893	101	21.903	1.039
	102	21.446	0.852	102	21.945	1.081
	103	21.446	0.852	103	21.945	1.081
	104	21.508	0.914	104	21.924	1.06
	105	21.467	0.873	105	21.945	1.081
	106	21.467	0.873	106	21.945	1.081
	107	21.508	0.914	107	21.945	1.081
	108	21.55	0.956	108	21.924	1.06
	109	21.529	0.935	109	21.965	1.101

	110	21.55	0.956	110	21.965	1.101
	111	21.55	0.956	111	21.965	1.101
	112	21.55	0.956	112	21.965	1.101
	113	21.571	0.977	113	21.986	1.122
	114	21.571	0.977	114	21.986	1.122
	115	21.571	0.977	115	21.986	1.122
	116	21.591	0.997	116	21.986	1.122
	117	21.529	0.935	117	22.007	1.143
	118	21.591	0.997	118	22.007	1.143
	119	21.591	0.997	119	21.986	1.122
	120	21.591	0.997	120	21.965	1.101
Min			-0.063			0
Max			0.997			1.143
Range			1.06			1.143

Raw temperature data: PAD Omni

PAD Omni						
Sample 1						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	20.947	0	0	21.342	0
	1	20.947	0	1	21.404	0.062
	2	20.947	0	2	21.404	0.062
	3	20.947	0	3	21.404	0.062
	4	20.926	-0.021	4	21.383	0.041
	5	20.926	-0.021	5	21.383	0.041
	6	20.926	-0.021	6	21.383	0.041
	7	20.926	-0.021	7	21.321	-0.021
	8	20.926	-0.021	8	21.383	0.041
	9	20.926	-0.021	9	21.321	-0.021
	10	20.926	-0.021	10	21.342	0
	11	20.947	0	11	21.3	-0.042
	12	20.926	-0.021	12	21.363	0.021
	13	20.947	0	13	21.363	0.021
	14	20.947	0	14	21.363	0.021
	15	20.947	0	15	21.363	0.021
	16	20.947	0	16	21.363	0.021
	17	20.947	0	17	21.3	-0.042
	18	20.947	0	18	21.3	-0.042
	19	20.947	0	19	21.342	0
	20	20.968	0.021	20	21.342	0
	21	20.947	0	21	21.342	0
	22	20.885	-0.062	22	21.342	0
	23	20.947	0	23	21.342	0
	24	20.947	0	24	21.342	0
	25	20.947	0	25	21.342	0
	26	20.947	0	26	21.342	0
	27	20.947	0	27	21.342	0
	28	20.947	0	28	21.342	0
	29	20.947	0	29	21.342	0
	30	20.947	0	30	21.342	0
	31	20.989	0.042	31	21.321	-0.021
	32	20.947	0	32	21.321	-0.021
	33	20.947	0	33	21.321	-0.021
	34	20.947	0	34	21.321	-0.021
	35	20.947	0	35	21.321	-0.021
	36	20.947	0	36	21.321	-0.021
	37	20.947	0	37	21.321	-0.021
	38	20.947	0	38	21.321	-0.021
	39	20.947	0	39	21.321	-0.021
	40	20.905	-0.042	40	21.321	-0.021
	41	20.926	-0.021	41	21.3	-0.042
	42	20.947	0	42	21.3	-0.042
	43	20.947	0	43	21.3	-0.042
	44	20.968	0.021	44	21.3	-0.042
	45	20.947	0	45	21.238	-0.104
	46	20.947	0	46	21.3	-0.042
	47	20.968	0.021	47	21.238	-0.104
	48	20.968	0.021	48	21.3	-0.042
	49	20.968	0.021	49	21.238	-0.104
	50	20.968	0.021	50	21.259	-0.083
	51	20.968	0.021	51	21.28	-0.062
	52	20.905	-0.042	52	21.28	-0.062
	53	20.968	0.021	53	21.3	-0.042
	54	20.989	0.042	54	21.28	-0.062
	55	20.926	-0.021	55	21.28	-0.062
	56	20.968	0.021	56	21.28	-0.062
	57	20.968	0.021	57	21.28	-0.062
	58	20.968	0.021	58	21.321	-0.021
	59	20.968	0.021	59	21.28	-0.062
	60	20.968	0.021	60	21.217	-0.125
	61	20.968	0.021	61	21.28	-0.062
	62	20.968	0.021	62	21.28	-0.062
	63	20.968	0.021	63	21.217	-0.125
	64	20.968	0.021	64	21.28	-0.062
	65	20.968	0.021	65	21.28	-0.062
	66	20.968	0.021	66	21.28	-0.062
	67	20.968	0.021	67	21.28	-0.062
	68	20.905	-0.042	68	21.28	-0.062
	69	20.968	0.021	69	21.28	-0.062
	70	20.989	0.042	70	21.28	-0.062
	71	20.926	-0.021	71	21.28	-0.062
	72	20.905	-0.042	72	21.259	-0.083
	73	20.968	0.021	73	21.259	-0.083
	74	20.968	0.021	74	21.259	-0.083
	75	20.905	-0.042	75	21.259	-0.083
	76	20.968	0.021	76	21.259	-0.083
	77	20.968	0.021	77	21.259	-0.083
	78	20.968	0.021	78	21.259	-0.083
	79	20.947	0	79	21.259	-0.083
	80	20.947	0	80	21.259	-0.083
	81	20.947	0	81	21.259	-0.083
	82	20.885	-0.062	82	21.259	-0.083
	83	20.947	0	83	21.259	-0.083
	84	20.885	-0.062	84	21.196	-0.146
	85	20.947	0	85	21.217	-0.125
	86	20.947	0	86	21.196	-0.146

	87	20.947	0	87	21.217	-0.125
	88	20.926	-0.021	88	21.196	-0.146
	89	20.947	0	89	21.259	-0.083
	90	20.926	-0.021	90	21.238	-0.104
	91	20.926	-0.021	91	21.238	-0.104
	92	20.926	-0.021	92	21.238	-0.104
	93	20.926	-0.021	93	21.238	-0.104
	94	20.926	-0.021	94	21.238	-0.104
	95	20.926	-0.021	95	21.238	-0.104
	96	20.926	-0.021	96	21.238	-0.104
	97	20.926	-0.021	97	21.238	-0.104
	98	20.926	-0.021	98	21.238	-0.104
	99	20.926	-0.021	99	21.238	-0.104
	100	20.947	0	100	21.238	-0.104
	101	20.885	-0.062	101	21.238	-0.104
	102	20.905	-0.042	102	21.217	-0.125
	103	20.905	-0.042	103	21.176	-0.166
	104	20.905	-0.042	104	21.217	-0.125
	105	20.905	-0.042	105	21.176	-0.166

	106	20.905	-0.042	106	21.217	-0.125
	107	20.905	-0.042	107	21.217	-0.125
	108	20.905	-0.042	108	21.217	-0.125
	109	20.905	-0.042	109	21.217	-0.125
	110	20.885	-0.062	110	21.217	-0.125
	111	20.885	-0.062	111	21.155	-0.187
	112	20.822	-0.125	112	21.217	-0.125
	113	20.885	-0.062	113	21.217	-0.125
	114	20.822	-0.125	114	21.217	-0.125
	115	20.885	-0.062	115	21.217	-0.125
	116	20.885	-0.062	116	21.217	-0.125
	117	20.864	-0.083	117	21.217	-0.125
	118	20.864	-0.083	118	21.217	-0.125
	119	20.822	-0.125	119	21.217	-0.125
	120	20.864	-0.083	120	21.196	-0.146
Min			-0.125			-0.187
Max			0.042			0.062
Range			0.167			0.249

PAD Omni						
Sample 2						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	22.069	0	0	21.487	0
	1	22.069	0	1	21.487	0
	2	22.049	-0.02	2	21.487	0
	3	21.965	-0.104	3	21.487	0
	4	21.945	-0.124	4	21.487	0
	5	21.945	-0.124	5	21.467	-0.02
	6	21.986	-0.083	6	21.404	-0.083
	7	21.986	-0.083	7	21.467	-0.02
	8	21.945	-0.124	8	21.467	-0.02
	9	21.945	-0.124	9	21.467	-0.02
	10	21.924	-0.145	10	21.425	-0.062
	11	21.882	-0.187	11	21.467	-0.02
	12	21.903	-0.166	12	21.467	-0.02
	13	21.882	-0.187	13	21.467	-0.02
	14	21.82	-0.249	14	21.467	-0.02
	15	21.862	-0.207	15	21.404	-0.083
	16	21.862	-0.207	16	21.467	-0.02
	17	21.841	-0.228	17	21.467	-0.02
	18	21.841	-0.228	18	21.467	-0.02
	19	21.82	-0.249	19	21.467	-0.02
	20	21.799	-0.27	20	21.467	-0.02
	21	21.799	-0.27	21	21.446	-0.041
	22	21.778	-0.291	22	21.383	-0.104
	23	21.695	-0.374	23	21.446	-0.041
	24	21.716	-0.353	24	21.446	-0.041
	25	21.737	-0.332	25	21.446	-0.041
	26	21.737	-0.332	26	21.446	-0.041
	27	21.654	-0.415	27	21.446	-0.041
	28	21.716	-0.353	28	21.446	-0.041
	29	21.695	-0.374	29	21.446	-0.041
	30	21.716	-0.353	30	21.404	-0.083
	31	21.654	-0.415	31	21.446	-0.041
	32	21.612	-0.457	32	21.467	-0.02
	33	21.612	-0.457	33	21.446	-0.041
	34	21.633	-0.436	34	21.425	-0.062
	35	21.591	-0.478	35	21.425	-0.062
	36	21.633	-0.436	36	21.363	-0.124
	37	21.612	-0.457	37	21.425	-0.062
	38	21.612	-0.457	38	21.425	-0.062
	39	21.591	-0.478	39	21.425	-0.062
	40	21.591	-0.478	40	21.425	-0.062
	41	21.591	-0.478	41	21.467	-0.02
	42	21.571	-0.498	42	21.425	-0.062
	43	21.508	-0.561	43	21.425	-0.062
	44	21.55	-0.519	44	21.425	-0.062
	45	21.571	-0.498	45	21.425	-0.062
	46	21.529	-0.54	46	21.425	-0.062
	47	21.529	-0.54	47	21.425	-0.062
	48	21.529	-0.54	48	21.425	-0.062
	49	21.508	-0.561	49	21.425	-0.062
	50	21.508	-0.561	50	21.425	-0.062
	51	21.508	-0.561	51	21.425	-0.062
	52	21.446	-0.623	52	21.425	-0.062
	53	21.487	-0.582	53	21.404	-0.083
	54	21.425	-0.644	54	21.363	-0.124
	55	21.467	-0.602	55	21.404	-0.083
	56	21.467	-0.602	56	21.342	-0.145
	57	21.446	-0.623	57	21.383	-0.104
	58	21.446	-0.623	58	21.404	-0.083
	59	21.446	-0.623	59	21.404	-0.083
	60	21.425	-0.644	60	21.363	-0.124
	61	21.425	-0.644	61	21.404	-0.083
	62	21.425	-0.644	62	21.404	-0.083
	63	21.404	-0.665	63	21.342	-0.145
	64	21.404	-0.665	64	21.404	-0.083
	65	21.404	-0.665	65	21.342	-0.145
	66	21.383	-0.686	66	21.404	-0.083
	67	21.383	-0.686	67	21.342	-0.145
	68	21.363	-0.706	68	21.383	-0.104
	69	21.363	-0.706	69	21.383	-0.104
	70	21.363	-0.706	70	21.383	-0.104
	71	21.342	-0.727	71	21.383	-0.104
	72	21.28	-0.789	72	21.383	-0.104
	73	21.342	-0.727	73	21.383	-0.104
	74	21.321	-0.748	74	21.383	-0.104
	75	21.321	-0.748	75	21.383	-0.104
	76	21.321	-0.748	76	21.321	-0.166
	77	21.321	-0.748	77	21.383	-0.104
	78	21.3	-0.769	78	21.383	-0.104
	79	21.3	-0.769	79	21.383	-0.104
	80	21.3	-0.769	80	21.383	-0.104
	81	21.321	-0.748	81	21.425	-0.062
	82	21.28	-0.789	82	21.383	-0.104
	83	21.217	-0.852	83	21.321	-0.166
	84	21.28	-0.789	84	21.342	-0.145
	85	21.259	-0.81	85	21.383	-0.104
	86	21.259	-0.81	86	21.383	-0.104
	87	21.259	-0.81	87	21.363	-0.124
	88	21.259	-0.81	88	21.383	-0.104
	89	21.259	-0.81	89	21.363	-0.124
	90	21.259	-0.81	90	21.321	-0.166
	91	21.196	-0.873	91	21.404	-0.083
	92	21.238	-0.831	92	21.363	-0.124
	93	21.238	-0.831	93	21.363	-0.124
	94	21.217	-0.852	94	21.363	-0.124

	95	21.217	-0.852	95	21.3	-0.187
	96	21.217	-0.852	96	21.363	-0.124
	97	21.155	-0.914	97	21.363	-0.124
	98	21.217	-0.852	98	21.363	-0.124
	99	21.196	-0.873	99	21.363	-0.124
	100	21.155	-0.914	100	21.363	-0.124
	101	21.134	-0.935	101	21.363	-0.124
	102	21.176	-0.893	102	21.363	-0.124
	103	21.176	-0.893	103	21.3	-0.187
	104	21.176	-0.893	104	21.363	-0.124
	105	21.176	-0.893	105	21.363	-0.124
	106	21.176	-0.893	106	21.363	-0.124
	107	21.155	-0.914	107	21.363	-0.124
	108	21.155	-0.914	108	21.342	-0.145
	109	21.155	-0.914	109	21.342	-0.145

	110	21.155	-0.914	110	21.342	-0.145
	111	21.155	-0.914	111	21.321	-0.166
	112	21.134	-0.935	112	21.3	-0.187
	113	21.072	-0.997	113	21.342	-0.145
	114	21.072	-0.997	114	21.342	-0.145
	115	21.072	-0.997	115	21.28	-0.207
	116	21.113	-0.956	116	21.342	-0.145
	117	21.051	-1.018	117	21.363	-0.124
	118	21.113	-0.956	118	21.342	-0.145
	119	21.113	-0.956	119	21.342	-0.145
	120	21.113	-0.956	120	21.28	-0.207
Min			-1.018			-0.207
Max			0			0
Range			1.018			0.207

PAD Omni

Sample 3

Zone 1			Zone 2		
Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
0	21.758	0	0	21.404	0
1	21.737	-0.021	1	21.404	0
2	21.737	-0.021	2	21.404	0
3	21.716	-0.042	3	21.404	0
4	21.716	-0.042	4	21.425	0.021
5	21.695	-0.063	5	21.425	0.021
6	21.674	-0.084	6	21.425	0.021
7	21.674	-0.084	7	21.363	-0.041
8	21.654	-0.104	8	21.425	0.021
9	21.591	-0.167	9	21.383	-0.021
10	21.633	-0.125	10	21.383	-0.021
11	21.633	-0.125	11	21.363	-0.041
12	21.571	-0.187	12	21.425	0.021
13	21.55	-0.208	13	21.425	0.021
14	21.55	-0.208	14	21.425	0.021
15	21.571	-0.187	15	21.425	0.021
16	21.571	-0.187	16	21.425	0.021
17	21.55	-0.208	17	21.425	0.021
18	21.529	-0.229	18	21.425	0.021
19	21.529	-0.229	19	21.425	0.021
20	21.467	-0.291	20	21.425	0.021
21	21.467	-0.291	21	21.425	0.021
22	21.446	-0.312	22	21.425	0.021
23	21.467	-0.291	23	21.425	0.021
24	21.425	-0.333	24	21.446	0.042
25	21.467	-0.291	25	21.446	0.042
26	21.467	-0.291	26	21.446	0.042
27	21.467	-0.291	27	21.446	0.042
28	21.446	-0.312	28	21.446	0.042
29	21.446	-0.312	29	21.446	0.042
30	21.446	-0.312	30	21.446	0.042
31	21.363	-0.395	31	21.446	0.042
32	21.383	-0.375	32	21.446	0.042
33	21.363	-0.395	33	21.446	0.042
34	21.363	-0.395	34	21.404	0
35	21.342	-0.416	35	21.467	0.063
36	21.404	-0.354	36	21.404	0
37	21.383	-0.375	37	21.383	-0.021
38	21.383	-0.375	38	21.446	0.042
39	21.363	-0.395	39	21.446	0.042
40	21.363	-0.395	40	21.446	0.042
41	21.363	-0.395	41	21.446	0.042
42	21.342	-0.416	42	21.383	-0.021
43	21.342	-0.416	43	21.404	0
44	21.342	-0.416	44	21.383	-0.021
45	21.321	-0.437	45	21.446	0.042
46	21.321	-0.437	46	21.446	0.042
47	21.321	-0.437	47	21.383	-0.021
48	21.321	-0.437	48	21.446	0.042
49	21.3	-0.458	49	21.383	-0.021
50	21.3	-0.458	50	21.446	0.042
51	21.3	-0.458	51	21.425	0.021
52	21.28	-0.478	52	21.446	0.042
53	21.28	-0.478	53	21.446	0.042
54	21.28	-0.478	54	21.446	0.042
55	21.28	-0.478	55	21.446	0.042
56	21.259	-0.499	56	21.446	0.042
57	21.259	-0.499	57	21.446	0.042
58	21.259	-0.499	58	21.446	0.042
59	21.259	-0.499	59	21.446	0.042
60	21.238	-0.52	60	21.446	0.042
61	21.196	-0.562	61	21.487	0.083
62	21.238	-0.52	62	21.446	0.042
63	21.238	-0.52	63	21.446	0.042
64	21.238	-0.52	64	21.446	0.042
65	21.217	-0.541	65	21.446	0.042
66	21.217	-0.541	66	21.446	0.042
67	21.217	-0.541	67	21.446	0.042
68	21.217	-0.541	68	21.446	0.042
69	21.217	-0.541	69	21.446	0.042
70	21.196	-0.562	70	21.446	0.042
71	21.176	-0.582	71	21.446	0.042
72	21.196	-0.562	72	21.446	0.042
73	21.196	-0.562	73	21.446	0.042
74	21.196	-0.562	74	21.467	0.063
75	21.134	-0.624	75	21.467	0.063
76	21.176	-0.582	76	21.446	0.042
77	21.155	-0.603	77	21.446	0.042
78	21.176	-0.582	78	21.404	0
79	21.176	-0.582	79	21.467	0.063
80	21.176	-0.582	80	21.404	0
81	21.134	-0.624	81	21.467	0.063
82	21.155	-0.603	82	21.467	0.063
83	21.155	-0.603	83	21.467	0.063
84	21.155	-0.603	84	21.467	0.063
85	21.155	-0.603	85	21.404	0
86	21.134	-0.624	86	21.467	0.063
87	21.134	-0.624	87	21.404	0
88	21.134	-0.624	88	21.404	0
89	21.134	-0.624	89	21.467	0.063
90	21.134	-0.624	90	21.467	0.063
91	21.134	-0.624	91	21.467	0.063
92	21.113	-0.645	92	21.467	0.063
93	21.113	-0.645	93	21.467	0.063
94	21.113	-0.645	94	21.467	0.063

	95	21.113	-0.645	95	21.467	0.063
	96	21.113	-0.645	96	21.467	0.063
	97	21.134	-0.624	97	21.467	0.063
	98	21.113	-0.645	98	21.467	0.063
	99	21.092	-0.666	99	21.467	0.063
	100	21.092	-0.666	100	21.467	0.063
	101	21.092	-0.666	101	21.508	0.104
	102	21.092	-0.666	102	21.467	0.063
	103	21.092	-0.666	103	21.467	0.063
	104	21.113	-0.645	104	21.467	0.063
	105	21.072	-0.686	105	21.467	0.063
	106	21.072	-0.686	106	21.487	0.083
	107	21.072	-0.686	107	21.467	0.063
	108	21.072	-0.686	108	21.467	0.063
	109	21.009	-0.749	109	21.467	0.063

	110	21.072	-0.686	110	21.467	0.063
	111	21.009	-0.749	111	21.508	0.104
	112	21.03	-0.728	112	21.467	0.063
	113	21.009	-0.749	113	21.404	0
	114	21.072	-0.686	114	21.467	0.063
	115	21.072	-0.686	115	21.467	0.063
	116	21.051	-0.707	116	21.404	0
	117	21.051	-0.707	117	21.425	0.021
	118	21.009	-0.749	118	21.404	0
	119	21.051	-0.707	119	21.467	0.063
	120	21.051	-0.707	120	21.467	0.063
Min			-0.749			-0.041
Max			0			0.104
Range			0.749			0.145

PAD Omni						
Sample 4						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	20.968	0	0	21.591	0
	1	20.968	0	1	21.654	0.063
	2	20.968	0	2	21.633	0.042
	3	20.947	-0.021	3	21.633	0.042
	4	20.947	-0.021	4	21.633	0.042
	5	20.885	-0.083	5	21.633	0.042
	6	20.864	-0.104	6	21.612	0.021
	7	20.864	-0.104	7	21.571	-0.02
	8	20.885	-0.083	8	21.571	-0.02
	9	20.864	-0.104	9	21.612	0.021
	10	20.905	-0.063	10	21.571	-0.02
	11	20.885	-0.083	11	21.591	0
	12	20.905	-0.063	12	21.591	0
	13	20.905	-0.063	13	21.591	0
	14	20.905	-0.063	14	21.529	-0.062
	15	20.905	-0.063	15	21.571	-0.02
	16	20.905	-0.063	16	21.571	-0.02
	17	20.885	-0.083	17	21.55	-0.041
	18	20.885	-0.083	18	21.55	-0.041
	19	20.885	-0.083	19	21.55	-0.041
	20	20.885	-0.083	20	21.55	-0.041
	21	20.926	-0.042	21	21.55	-0.041
	22	20.885	-0.083	22	21.529	-0.062
	23	20.905	-0.063	23	21.529	-0.062
	24	20.843	-0.125	24	21.529	-0.062
	25	20.822	-0.146	25	21.529	-0.062
	26	20.885	-0.083	26	21.529	-0.062
	27	20.864	-0.104	27	21.508	-0.083
	28	20.905	-0.063	28	21.508	-0.083
	29	20.864	-0.104	29	21.508	-0.083
	30	20.864	-0.104	30	21.508	-0.083
	31	20.864	-0.104	31	21.508	-0.083
	32	20.864	-0.104	32	21.487	-0.104
	33	20.843	-0.125	33	21.487	-0.104
	34	20.843	-0.125	34	21.487	-0.104
	35	20.843	-0.125	35	21.487	-0.104
	36	20.781	-0.187	36	21.487	-0.104
	37	20.843	-0.125	37	21.446	-0.145
	38	20.843	-0.125	38	21.425	-0.166
	39	20.781	-0.187	39	21.467	-0.124
	40	20.822	-0.146	40	21.467	-0.124
	41	20.76	-0.208	41	21.467	-0.124
	42	20.822	-0.146	42	21.467	-0.124
	43	20.822	-0.146	43	21.404	-0.187
	44	20.801	-0.167	44	21.467	-0.124
	45	20.801	-0.167	45	21.446	-0.145
	46	20.801	-0.167	46	21.446	-0.145
	47	20.801	-0.167	47	21.446	-0.145
	48	20.801	-0.167	48	21.383	-0.208
	49	20.76	-0.208	49	21.383	-0.208
	50	20.801	-0.167	50	21.383	-0.208
	51	20.801	-0.167	51	21.446	-0.145
	52	20.739	-0.229	52	21.425	-0.166
	53	20.801	-0.167	53	21.425	-0.166
	54	20.781	-0.187	54	21.425	-0.166
	55	20.781	-0.187	55	21.363	-0.228
	56	20.781	-0.187	56	21.425	-0.166
	57	20.781	-0.187	57	21.363	-0.228
	58	20.781	-0.187	58	21.425	-0.166
	59	20.781	-0.187	59	21.425	-0.166
	60	20.781	-0.187	60	21.404	-0.187
	61	20.822	-0.146	61	21.404	-0.187
	62	20.781	-0.187	62	21.404	-0.187
	63	20.801	-0.167	63	21.404	-0.187
	64	20.76	-0.208	64	21.404	-0.187
	65	20.76	-0.208	65	21.404	-0.187
	66	20.76	-0.208	66	21.404	-0.187
	67	20.76	-0.208	67	21.404	-0.187
	68	20.76	-0.208	68	21.404	-0.187
	69	20.76	-0.208	69	21.383	-0.208
	70	20.76	-0.208	70	21.383	-0.208
	71	20.698	-0.27	71	21.425	-0.166
	72	20.698	-0.27	72	21.383	-0.208
	73	20.76	-0.208	73	21.383	-0.208
	74	20.698	-0.27	74	21.383	-0.208
	75	20.718	-0.25	75	21.383	-0.208
	76	20.739	-0.229	76	21.321	-0.27
	77	20.739	-0.229	77	21.383	-0.208
	78	20.739	-0.229	78	21.321	-0.27
	79	20.739	-0.229	79	21.383	-0.208
	80	20.739	-0.229	80	21.321	-0.27
	81	20.739	-0.229	81	21.363	-0.228
	82	20.739	-0.229	82	21.363	-0.228
	83	20.677	-0.291	83	21.363	-0.228
	84	20.739	-0.229	84	21.363	-0.228
	85	20.677	-0.291	85	21.3	-0.291
	86	20.718	-0.25	86	21.383	-0.208
	87	20.718	-0.25	87	21.363	-0.228
	88	20.718	-0.25	88	21.363	-0.228
	89	20.718	-0.25	89	21.363	-0.228
	90	20.718	-0.25	90	21.383	-0.208
	91	20.718	-0.25	91	21.321	-0.27
	92	20.718	-0.25	92	21.363	-0.228
	93	20.718	-0.25	93	21.342	-0.249
	94	20.698	-0.27	94	21.363	-0.228

	95	20.698	-0.27	95	21.342	-0.249
	96	20.698	-0.27	96	21.342	-0.249
	97	20.698	-0.27	97	21.3	-0.291
	98	20.698	-0.27	98	21.342	-0.249
	99	20.698	-0.27	99	21.342	-0.249
	100	20.698	-0.27	100	21.342	-0.249
	101	20.698	-0.27	101	21.342	-0.249
	102	20.698	-0.27	102	21.342	-0.249
	103	20.698	-0.27	103	21.342	-0.249
	104	20.635	-0.333	104	21.342	-0.249
	105	20.698	-0.27	105	21.342	-0.249
	106	20.698	-0.27	106	21.342	-0.249
	107	20.698	-0.27	107	21.28	-0.311
	108	20.698	-0.27	108	21.342	-0.249
	109	20.698	-0.27	109	21.342	-0.249

	110	20.614	-0.354	110	21.342	-0.249
	111	20.677	-0.291	111	21.342	-0.249
	112	20.614	-0.354	112	21.28	-0.311
	113	20.677	-0.291	113	21.3	-0.291
	114	20.614	-0.354	114	21.342	-0.249
	115	20.677	-0.291	115	21.342	-0.249
	116	20.677	-0.291	116	21.342	-0.249
	117	20.677	-0.291	117	21.342	-0.249
	118	20.698	-0.27	118	21.342	-0.249
	119	20.677	-0.291	119	21.342	-0.249
	120	20.656	-0.312	120	21.342	-0.249
Min			-0.354			-0.311
Max			0			0.063
Range			0.354			0.374

PAD Omni						
Sample 5						
	Zone 1			Zone 2		
	Time(s)	Temp(ºC)	ΔTemp(ºC)	Time(s)	Temp(ºC)	ΔTemp(ºC)
	0	20.864	0	0	21.092	0
	1	20.864	0	1	21.03	-0.062
	2	20.843	-0.021	2	21.092	0
	3	20.822	-0.042	3	21.092	0
	4	20.801	-0.063	4	21.03	-0.062
	5	20.801	-0.063	5	21.092	0
	6	20.781	-0.083	6	21.092	0
	7	20.76	-0.104	7	21.092	0
	8	20.76	-0.104	8	21.03	-0.062
	9	20.739	-0.125	9	21.051	-0.041
	10	20.739	-0.125	10	21.03	-0.062
	11	20.718	-0.146	11	21.051	-0.041
	12	20.718	-0.146	12	21.03	-0.062
	13	20.698	-0.166	13	21.092	0
	14	20.698	-0.166	14	21.092	0
	15	20.698	-0.166	15	21.092	0
	16	20.677	-0.187	16	21.092	0
	17	20.677	-0.187	17	21.092	0
	18	20.656	-0.208	18	21.092	0
	19	20.656	-0.208	19	21.051	-0.041
	20	20.635	-0.229	20	21.092	0
	21	20.635	-0.229	21	21.03	-0.062
	22	20.614	-0.25	22	21.092	0
	23	20.573	-0.291	23	21.03	-0.062
	24	20.594	-0.27	24	21.072	-0.02
	25	20.573	-0.291	25	21.092	0
	26	20.531	-0.333	26	21.113	0.021
	27	20.552	-0.312	27	21.072	-0.02
	28	20.594	-0.27	28	21.092	0
	29	20.531	-0.333	29	21.072	-0.02
	30	20.552	-0.312	30	21.072	-0.02
	31	20.49	-0.374	31	21.072	-0.02
	32	20.531	-0.333	32	21.092	0
	33	20.531	-0.333	33	21.092	0
	34	20.531	-0.333	34	21.092	0
	35	20.531	-0.333	35	21.092	0
	36	20.51	-0.354	36	21.072	-0.02
	37	20.51	-0.354	37	21.072	-0.02
	38	20.51	-0.354	38	21.072	-0.02
	39	20.49	-0.374	39	21.113	0.021
	40	20.49	-0.374	40	21.072	-0.02
	41	20.469	-0.395	41	21.072	-0.02
	42	20.49	-0.374	42	21.072	-0.02
	43	20.49	-0.374	43	21.072	-0.02
	44	20.469	-0.395	44	21.072	-0.02
	45	20.469	-0.395	45	21.092	0
	46	20.469	-0.395	46	21.009	-0.083
	47	20.448	-0.416	47	21.051	-0.041
	48	20.448	-0.416	48	21.072	-0.02
	49	20.448	-0.416	49	21.072	-0.02
	50	20.448	-0.416	50	21.03	-0.062
	51	20.427	-0.437	51	21.072	-0.02
	52	20.427	-0.437	52	21.072	-0.02
	53	20.448	-0.416	53	21.072	-0.02
	54	20.427	-0.437	54	21.072	-0.02
	55	20.365	-0.499	55	21.03	-0.062
	56	20.427	-0.437	56	21.072	-0.02
	57	20.407	-0.457	57	21.03	-0.062
	58	20.407	-0.457	58	21.051	-0.041
	59	20.407	-0.457	59	21.009	-0.083
	60	20.407	-0.457	60	21.072	-0.02
	61	20.407	-0.457	61	21.092	0
	62	20.386	-0.478	62	21.072	-0.02
	63	20.365	-0.499	63	21.072	-0.02
	64	20.323	-0.541	64	21.072	-0.02
	65	20.386	-0.478	65	21.072	-0.02
	66	20.407	-0.457	66	21.072	-0.02
	67	20.344	-0.52	67	21.072	-0.02
	68	20.365	-0.499	68	21.072	-0.02
	69	20.386	-0.478	69	21.072	-0.02
	70	20.365	-0.499	70	21.092	0
	71	20.365	-0.499	71	21.072	-0.02
	72	20.365	-0.499	72	21.03	-0.062
	73	20.365	-0.499	73	21.072	-0.02
	74	20.365	-0.499	74	21.072	-0.02
	75	20.365	-0.499	75	21.092	0
	76	20.365	-0.499	76	21.072	-0.02
	77	20.303	-0.561	77	21.072	-0.02
	78	20.344	-0.52	78	21.072	-0.02
	79	20.344	-0.52	79	21.03	-0.062
	80	20.344	-0.52	80	21.072	-0.02
	81	20.344	-0.52	81	21.113	0.021
	82	20.344	-0.52	82	21.072	-0.02
	83	20.344	-0.52	83	21.03	-0.062
	84	20.344	-0.52	84	21.051	-0.041
	85	20.344	-0.52	85	21.072	-0.02
	86	20.323	-0.541	86	21.072	-0.02
	87	20.323	-0.541	87	21.072	-0.02
	88	20.323	-0.541	88	21.072	-0.02
	89	20.323	-0.541	89	21.072	-0.02
	90	20.323	-0.541	90	21.009	-0.083
	91	20.303	-0.561	91	21.009	-0.083
	92	20.261	-0.603	92	21.03	-0.062
	93	20.323	-0.541	93	21.072	-0.02
	94	20.344	-0.52	94	21.03	-0.062

	95	20.303	-0.561	95	21.051	-0.041
	96	20.303	-0.561	96	21.072	-0.02
	97	20.303	-0.561	97	21.072	-0.02
	98	20.303	-0.561	98	21.072	-0.02
	99	20.303	-0.561	99	21.072	-0.02
	100	20.303	-0.561	100	21.072	-0.02
	101	20.323	-0.541	101	21.113	0.021
	102	20.303	-0.561	102	21.072	-0.02
	103	20.323	-0.541	103	21.009	-0.083
	104	20.303	-0.561	104	21.072	-0.02
	105	20.303	-0.561	105	21.072	-0.02
	106	20.303	-0.561	106	21.072	-0.02
	107	20.303	-0.561	107	21.072	-0.02
	108	20.303	-0.561	108	21.009	-0.083
	109	20.282	-0.582	109	21.03	-0.062

	110	20.219	-0.645	110	21.009	-0.083
	111	20.282	-0.582	111	21.051	-0.041
	112	20.282	-0.582	112	21.072	-0.02
	113	20.282	-0.582	113	21.072	-0.02
	114	20.282	-0.582	114	21.072	-0.02
	115	20.282	-0.582	115	21.072	-0.02
	116	20.261	-0.603	116	21.072	-0.02
	117	20.261	-0.603	117	21.072	-0.02
	118	20.261	-0.603	118	21.072	-0.02
	119	20.219	-0.645	119	21.009	-0.083
	120	20.261	-0.603	120	21.072	-0.02
Min			-0.645			-0.083
Max			0			0.021
Range			0.645			0.104